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CONTENTS

Influence of Gestation. LEROY S. PALMER and C. H. ECKLES 183
What is Meant by "Quality" in Milk. H. A. HARDING, R. S. BREED, W. A. STOCKING, JR. and E. G. HASTINGS 199
Concerning Rancidity of Butter. E. S. GUTHRIE 213
Composition and Market Qualities of Butter. L. S. PALMER and D. P. CROCKETT 235
Daily per Capita Consumption of Milk. H. F. JUDKINS 249
A Study of Preparation of Fermented Milk. R. FINKELSTEIN 260
Control of Public Milk Supplies by the use of the Microscopic Method. ROBERT S. BREED and JAMES D. BREW 269
Bacteriological Tests of Milk Clarifier. JAMES M. SHERMAN 272
Salt Test. F. W. BOUSKA 279
Plan for Control of Milk Supply in Small Cities. PERCY WERNER, JR. 284

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THE INFLUENCE OF THE STAGE OF GESTATION ON THE COMPOSITION AND PROPERTIES OF MILK

LEROY S. PALMER AND C. H. ECKLES

Department of Dairy Husbandry, University of Missouri, Columbia

Among the numerous factors which exert an influence upon the composition and properties of milk, that of the stage of gestation, or pregnancy, has received practically no attention from an experimental point of view. In spite of the fact that the data on this question are exceedingly meagre, there is a wide-spread belief among medical men that the composition and properties of cows' milk are influenced by pregnancy, and an equally wide-spread opinion held by both physicians and laymen that pregnancy and lactation in the human are incompatible, and that the pregnant woman must wean her child because of the marked influence which pregnancy exerts on the composition of the milk. As evidence of this belief among physicians may be cited the fact that all regulations[1] standardizing cows' milk for human consumption exclude its use for a period of time before parturition, on the ground that cows' milk no longer has a normal composition after gestation has reached a certain stage. The authors have recently shown (1) that this assumption cannot be supported by experimental evidence.

Data which the authors have already published (2) in connection with the influence of other factors on the composition of cows' milk have been found to contain important evidence on the question of the influence which is exerted by gestation. It is the purpose of this paper to present that portion of the data which has a bearing on this question. In addition, data which have not yet been published will be presented on the influence which gestation exerts upon the composition of human milk.

[1] For example, the standards adopted for "Certified Milk" by the American Association of Medical Milk Commissions (Proc. Sixth Ann. Conference, Am. Assn. Med. Milk Comm., 1912, p. 124) exclude the milk for a period of forty-five days before parturition.

INFLUENCE OF GESTATION ON COWS' MILK

The data available for the study of this question consisted of the complete analyses of the milk and milk fat throughout the entire lactation period of ten cows which became pregnant at various stages of their lactation period, of one cow which was farrow, and the complete analyses of the milk for three of the ten cows throughout a subsequent lactation when they were kept farrow.

It is now well known that the percentage composition of cows' milk and the constitution of the milk fat, as shown by the physical and chemical constants, undergo certain definite changes as the stage of lactation progresses. These changes are usually particularly marked at the close of lactation. Since, under normal conditions, nearly all cows are bred at some stage of their lactation period, it is difficult to determine how much the fact of pregnancy or the stage of gestation contribute to these changes in the composition of the milk and milk fat.

The completeness of the data for the lactation periods of the experimental animals has made it possible to compare the composition of the milk and the milk fat at any stage of lactation with the average composition for the entire period. Inasmuch as the date of breeding of the animals occurred at different stages of lactation for each of the animals it has been possible to ascertain at what stage of lactation the composition of the milk and milk fat of each animal showed permanent changes from the average, and to note, at the same time, at what stage of gestation these changes took place. This seemed to be the fairest way to compare the relative effects of the stages of lactation and gestation upon the composition of the milk, for it seemed probable that there should be some uniformity among the different animals with regard to the stage of duration of that factor contributing the strongest influence upon the composition of the milk.

Tabulation of the results from this standpoint revealed the fact, however, that permanent changes from the average composition of the fat occurred several weeks sooner, on the average, than similar changes in the percentage composition of the milk.

The two phases of the problem have accordingly been treated separately in the tabulation of the data.

In table 1 is shown the average composition of the milk for the entire lactation period of eleven cows, one of which was farrow, in comparison with the composition of the seven-day composite which showed the first permanent change from the average, and the stages of lactation and gestation when this change occurred. Similar data for the physical and chemical constants of the milk fat are shown in table 2. The data are arranged in each case in the order of the stage of lactation when gestation began.

TABLE 1

Average composition of milk for entire lactation period of eleven cows in comparison with the composition of seven day composite showing first permanent change from the average, and the stages of lactation and gestation when this change occurred

COW	STAGE OF LACTATION WHEN BRED	STAGE OF LACTATION		STAGE OF GESTATION	TOTAL SOLIDS	PROTEIN N. × 6.38	CASEIN N. × 6.38	FAT	LACTOSE
	days	*days*	*per cent*	*days*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
4	47	Average for year			14.08	3.70	2.95	4.87	4.85
4		249	77	202		3.89	3.19	4.89	4.52
300	58	Average for year			12.10	3.11	2.63	3.51	4.85
300		226	75	167	12.26	3.25	3.00	3.55	5.13
402	70	Average for year			13.50	3.49	2.85	4.13	4.91
402		238	85	168	13.30	3.89	3.13	4.51	4.72
99	82	Average for year			13.43	3.27	2.65	4.64	4.95
99		264	78	182	13.85	3.45	2.87	4.74	4.80
209	122	Average for year			11.30	3.21	2.52	3.10	4.25
209		253	72	131	11.62	3.45	2.74	2.85	4.72
400	118	Average for year			13.10	3.40	2.77	3.89	5.04
400		244	80	126	13.03	3.77	2.93	3.91	4.55
206	121	Average for year			10.70	2.70	2.12	2.93	4.26
206		268	84	147	12.10	3.13	2.61	3.35	4.06
205	137	Average for year			12.00	3.00	2.46	3.23	5.05
205		312	79	175	12.19	3.32	2.87	3.50	4.94
403	148	Average for year			12.20	3.28	2.61	3.37	4.98
403		229	63	81	13.01	3.83	3.19	3.83	4.22
301	172	Average for year			12.70	3.33	2.78	3.85	4.96
301		323	86	152	13.10	3.64	3.25	4.01	5.02
118	Farrow	Average for year			14.83	3.97	3.14	5.36	4.80
118		339	82.5	Farrow	15.25	4.41	3.34	5.54	4.63
Average.....		288	78.3						

Before discussing these tables it may be well to point out that complete information in regard to the character of the food consumed by the cows, their milk flow, and the methods employed in the care of the animals, and the care and analyses of the samples has been given in former publications (2, a, c,) and will not be repeated here. It may be mentioned, however, that the animals were all pure-bred dairy animals, representing the Jersey, Holstein, Ayreshire and Shorthorn breeds, and were bred and raised by the University of Missouri.

An examination of the data in table 1 shows a close relation existing between a change in the percentage composition of the milk and the stage of the lactation period, particularly with respect to the relative stage of lactation. The data fail to reveal, however, that the changes in the composition of the milk bore any constant relation to the stage of gestation. Similar results are obtained on examination of the data in table 2, dealing with the composition of the milk fat. Although the relations between the changes in the constitution of the milk fat and the stage of lactation is much less constant, the same result holds true with respect to the relation to the stage of gestation. It would appear that some other factor may have been partly responsible for the changes in the composition of the milk fat.

Still more substantial evidence in regard to the influence of the stage of gestation on the composition of milk is furnished by a comparison of the composition on corresponding days of two lactation periods of the same cow, during one period of which she is pregnant and the other farrow. Such data are available for three of the cows mentioned in tables 1 and 2, namely cows 4, 206 and 400, and are presented in tables 3, 4 and 5. The stage of the lactation for which the composition of the milk is given is shown for both the lactation periods in the second column of each table. The stage of gestation at this time for the period during which pregnancy occurred is given in the first column. The tables also show the milk flow in pounds per day at each stage of the two lactation periods.

An examination of the data in tables 3, 4 and 5 shows that the same shrinkage in milk flow and the same changes in the com-

position of the milk occurred at the end of the farrow lactation as took place at the end of the pregnant lactation, but at a somewhat later stage. The slightly less effects of advanced lactation in the farrow period of cow 206 were undoubtedly due

TABLE 2

Average constitution of fat for entire lactation period of eleven cows in comparison with the composition of the seven-day composite showing first permanent change from the average, and the stages of lactation and gestation when this change occurred

COW	STAGE OF LACTATION WHEN BRED	STAGE OF LACTATION		STAGE OF GESTATION	SAPONIFICATION VALUE	REICHERT-MEISSL NUMBER	IODIN VALUE	MELTING POINT
	days	*days*	*per cent*	*days*			*Hübl.*	*°C.*
4	47	Average for year			231.3	28.17	29.99	32.91
4		249	76.8	202	227.3	25.75	32.91	32.90
300	58	Average for year			228.4	26.34	31.14	33.75
300		184	61.5	125	224.3	24.76	34.23	34.48
402	70	Average for year			227.9	25.55	34.09	33.37
402		168	60.0	98	225.2	23.53	35.39	33.73
99	82	Average for year			228.6	28.69	28.78	32.95
99		306	90.6	224	227.9	25.30	34.62	35.70
209	122	Average for year			229.1	24.44	35.48	32.02
209		265	74.0	138	218.0	20.31	37.80	34.85
400	118	Average for year			227.6	26.89	34.08	33.56
400		258	84.0	140	222.5	24.73	35.84	35.38
206	121	Average for year			230.1	26.13	32.68	32.87
206		198	62.0	77	231.9	22.29	35.16	32.20
205	137	Average for year			228.2	25.81	34.46	33.76
205		312	79.0	175	224.5	24.41	36.44	32.95
403	148	Average for year			227.9	26.29	34.72	32.89
403		222	62.5	74	224.2	23.58	37.16	32.55
301	172	Average for year			228.2	25.52	32.06	33.20
301		247	65.8	75	227.2	24.11	33.81	32.69
118	Farrow	Average for year			228.9	23.28	32.79	32.99
118		339	82.5	Farrow	219.4	21.19	34.97	33.33
Average.....		244	72.6					

to the fact that her flow of milk was much heavier throughout the entire period, and persisted up to the very close of lactation.

It was unfortunate from the point of view of the present discussion that the data taken during the farrow period of cows 4, 206 and 400 did not include the physical and chemical constants

TABLE 3

Composition of milk of cow 4 during corresponding stage of successive lactation periods

STAGE OF GESTATION 1906–1907	STAGE OF LACTATION. 1906–1907 PREGNANT, 1907–1908 FARROW	MILK FLOW		TOTAL PROTEIN N. × 6.38		FAT		LACTOSE	
		When pregnant	When farrow	When pregnant	When farrow	When pregnant	When farrow	When pregnant	When farrow
30 days ending with	*30 days ending with*	*pounds per day*	*pounds per day*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
*	51	27.5	26.4	3.32	4.02	5.17	5.18	4.89	4.97
34	81	25.4	21.6	3.32	4.08	4.85	5.67	4.99	3.83
62	111	19.8	21.4	3.77	3.96	4.96	5.80	4.87	
97	142	20.1	20.8	3.89	3.96	4.85	5.95	5.07	4.10
125	171	18.7	20.8	3.80	4.15	5.00	5.97	5.20	4.20
153	201	16.9	17.5	3.71	4.02	4.73	6.10	4.39	4.70
188	232	16.5	15.1	3.68	4.21	4.51	5.72	4.95	4.60
216	261	13.5	15.1	3.89	4.27	4.73	5.40	4.67	4.10
244	291	16.2	16.3	4.21	4.08	5.05	5.17	4.64	4.41
272†	319	11.3	15.8	5.26	4.15	5.84	4.67	4.60	4.36
	351		14.2		4.34		5.00		4.16
	368‡§		10.1		4.47		5.20		4.36

* Gestation began on 47th day of lactation in 1906–07.

† Lactation ended on 324th day, the day of next parturition.

‡ Lactation ended on 368th day.

§ Last period sixteen days.

TABLE 4

Composition oj the milk of cow 206 during corresponding stages of two lactation periods

STAGE OF GESTATION 1907–1908	STAGE OF LACTATION. 1907–1908 PREGNANT, 1910–1911 FARROW	MILK FLOW		TOTAL PROTEIN N. × 6.38		FAT		LACTOSE	
		When pregnant	When farrow	When pregnant	When farrow	When pregnant	When farrow	When pregnant	When farrow
7–10 days ending with	*7–10 days ending with*	*pounds per day*	*pounds per day*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
*	100	31.1	40.3	2.42	2.89	2.76	3.44	4.06	4.35
7	128	30.6	41.3	2.68	2.76	2.72	3.56	4.32	4.08
35	156	27.6	37.7	2.68	2.96	3.13	3.80	4.14	4.06
56	177	25.7	34.9	2.62	2.97	3.05	3.81	4.20	4.16
84	205	25.0	32.6	2.68	2.83	3.08	3.55	4.22	4.30
105	226	25.0	35.6	2.87	3.00	3.23	2.70	3.69	4.19
133	254	22.2	32.5	2.81	2.98	3.06	2.87	4.23	4.27
154	275	20.0	29.7	3.38	2.95	3.03	3.49	4.09	4.27
175	296	8.1	28.0	4.34	3.17	3.44	3.33	4.68	4.25
189†	310	8.0	26.9	4.91	3.05	3.73	2.93	4.48	4.08
	346		18.9		3.20		3.21		3.70
	386‡		18.8		3.15		3.52		4.14

* Gestation began on 121st day of lactation in 1907–1908.

† Lactation ended on 310th day.

‡ Lactation ended on 386th day.

of the milk fat. In view of the data shown in table 2 for cow 118, which was farrow throughout her entire lactation period, it seems safe to assume that the same character of change in the constitution of the milk fat of cows 4, 206 and 400 would have occurred during their farrow lactation periods as occurred during their pregnant lactation periods.

The conclusion which we draw from the data which have been presented is that gestation does not exert any direct effect upon

TABLE 5

Composition of the milk of cow 400 during corresponding stages of two lactation periods

STAGE OF GESTATION 1907–1908	STAGE OF LACTATION. 1907–1908 PREGNANT, 1910–1911 FARROW	MILK FLOW		TOTAL PROTEIN N. × 6.38		FAT		LACTOSE	
		When pregnant	When farrow	When pregnant	When farrow	When pregnant	When farrow	When pregnant	When farrow
7–10 days ending with	*7–8 DAYS ending with*	*pounds per day*	*pounds per day*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
*	100	17.9	20.7	2.87	3.57	3.30	3.75	5.01	4.60
7	125	20.2	19.3	3.25	3.53	3.53	3.75	4.93	4.66
35	153	19.3	16.4	3.38	3.37	3.62	4.10	5.39	4.92
63	187	17.9	16.6	3.51	3.36	3.52	3.45	5.28	4.48
84	202	17.9	16.7	3.51	3.40	3.95	3.70	5.30	4.65
105	223	18.5	15.7	3.57	3.41	3.96	3.61	5.09	4.75
133	251	15.1	14.2	3.83	3.52	4.52	3.92	4.54	4.72
154	272	7.8	9.4	3.83	3.79	4.78	4.27	3.80	4.10
175	293	5.1	8.1	3.89	3.52	4.28	4.20	3.90	4.10
189†	307	5.1	7.4	3.70	3.61	4.20	4.28	4.29	3.60
	331		6.1		3.53		4.70		2.15
	371‡		5.5		3.51		4.22		4.51

* Gestation began on 118th day of lactation, 1907–1908.

† Lactation ended 307th day.

‡ Lactation ended 371st day.

the composition and properties of cows' milk, but that gestation may affect the composition indirectly by hastening the close of lactation, which is the important factor involved in the changes in the composition of milk as lactation advances.

INFLUENCE OF GESTATION ON HUMAN MILK

Data relative to the effect of gestation on the composition of human milk are both meagre and contradictory, although the

subject has been discussed to a certain extent in the medical literature. Practically the only analyses bearing on this question which the authors have been able to find were made by Davis (3) a great many years ago. They are presented in table 6.

In addition the author observed that the milk of each of the pregnant women contained a few bodies like colostrum corpuscles, and also numerous cell-like structures and exceedingly small, but very active animalcula. Sketches of the microscopic fields are given. The animalcula were also found in the milk of the women when they were not pregnant, but they were not so numerous.

Davis concluded that, "The occurrence of pregnancy during lactation produces a very marked diminution of all the solid

TABLE 6

Influence of pregnancy on human milk (Davis)

SUBJECT	TIME OF LACTATION	TIME OF GESTATION	TOTAL SOLIDS	CASEIN	FAT	SUGAR	SALTS
	months	*months*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Mrs. B.....	11	6	5.79	2.31	1.26	2.11	0.11
Mrs. B.....	4*	0	11.34	5.79	2.29	2.85	0.41
Mrs. G.....	8	3	6.74	2.53	1.68	2.21	0.21
Mrs. G.....	3*	0	11.71	4.15	3.90	3.17	0.49

* Data taken in succeeding lactation.

or nutritive constituents of the milk, such diminution continuing to increase as the pregnancy advances." The methods of analysis used are not given in the report, but considerable doubt is thrown on the accuracy of the results on account of the high percentage of casein and low percentage of sugar reported for the samples of normal milk. It is now well-established that normal human milk contains relatively little casein, and frequently as high as 7 per cent lactose.

The author also reports clinical observations of the children whose mothers became pregnant during lactation. In each case serious digestive and nutritional disturbances followed very soon after pregnancy began and became more and more serious as long as the mothers persisted in nursing the children. In

the case of Mrs. B. this continued for six months when the child presented the appearance of extreme emaciation and anemia. The child of Mrs. G. showed a similar condition at the end of two months of its mother's pregnancy. Both children died within a few weeks after changing them to other food, the cause of death being attributed, however, in one case to "subacute meningeal inflammation," and in the other case to cholera morbus.

Davis also reports clinical observations of four other women who became pregnant while nursing. In each case but one, in which pregnancy occurred during the sixth month of lactation, the children began to exhibit symptoms of imperfect digestion and nutrition within two months, and continued to do so until removed from the breast. In the exceptional case it was the mother who became anemic and was forced to wean her child after the fifth month of gestation.

Similar clinical evidence has more recently been reported by Guida (4), who states that it is rare to find in practice that a child nursed by a pregnant woman prospers and keeps in good health. As a rule they are dyspeptic, restless, irritable, pale, sleep little, and do not increase normally in weight. Guida attributes this to a scanty milk flow, and to the fact that the milk is rich in casein. The author claims to have established that there are no special substances injurious to the child, which are developed in the milk of a pregnant woman. We are not able to present his data on this point as the original paper of Guida's was not accessible.

Children nursed by pregnant mothers invariably show a rise in temperature, according to Guida, but the reason for this is not clear. He states that healthy children invariably grow ill and feverish if nursed by a pregnant woman. These symptoms are shown by twelve months old children, even when they receive other food in addition to the mother's milk. The author was not able to produce any pathological effects, however, by injecting this milk into animals.

Still another view of the effects of gestation during lactation is held by Fordyce (5), who concludes from his observations, that, "Where pregnancy and lactation overlap the foetus is likely to suffer."

The data which we have to offer on the question of the influence of gestation on the composition of human milk represent the analyses of twelve-hour composites of milk[2] of two negro

TABLE 7

Percentage composition of the milk of S. H. during portions of lactation and gestation periods which overlapped

TWELVE HOUR COMPOSITE FOR THE WEEK ENDING	VOLUME OF MILK	STAGE OF LACTATION	APPROXIMATE STAGE OF GESTATION	SPECIFIC GRAVITY OF MILK	TOTAL SOLIDS	TOTAL PROTEIN N. × 6.38	FAT	SUGAR
1908	*cc.*	*days*	*days*		*per cent*	*per cent*	*per cent*	*per cent*
September 10	60	370		1.0338	10.46	1.28	1.79	7.83
September 17	40	377		1.0334	10.85	1.08	2.31	7.48
September 24	45	384		1.0349	12.18	1.08	3.57	7.50
October 3	60	391		1.0300	12.50	1.02	4.02	6.58
October 10	50	398		1.0300	12.14	1.15	3.46	7.25
October 17	100	405		1.0329	12.17	1.08	3.95	6.73
October 24	115	412		1.0327	12.35	1.02	3.73	7.06
October 31	130	419		1.0331	10.93	1.02	2.54	7.20
November 7		426		1.0335	9.92	1.02	1.20	7.21
November 14	75	433	3	1.0255	12.90	1.02	4.51	
November 21	105	440	10	1.0310	10.31	0.89	2.01	6.70
November 28	170	447	17	1.0280	11.19	0.96	3.26	6.95
December 5	70	454	24					7.53
December 12	120	461	31	1.0313	10.66	1.02	1.68	6.67
December 19	122	468	38	1.0282	11.50	1.02	3.29	6.99
December 26	40	475	45	1.0256	15.29	1.15	7.42	
1909								
January 2	85	482	52	1.0293	10.81	1.15	2.48	6.73
January 9	115	489	59	1.0256	13.05	1.28	4.99	6.55
January 16	70	496	66	1.0231	13.41	1.40	5.16	6.15
January 23	77	503	73	1.0290	12.30	1.34	4.25	4.21
January 30	62	510	80	1.0300	13.25	1.79	4.97	6.00
February 6	30	517	87	1.0230	15.76	2.30	7.58	

women, the samples being taken in each case from the same breast at weekly intervals during portions of periods of lactation and gestation which overlapped. These data are shown in tables

[2] These samples were taken and the analyses made under the direction of Mr. R. H. Shaw of the Dairy Division, United States Department of Agriculture, at the time of his connection with this laboratory. The data will form a part of a more complete report of the influence of the stage of lactation on the composition of human milk which is to be published later by the Dairy Division. The authors are greatly indebted to Mr. Shaw for the use of the data.

7 and 8, together with the stages of lactation and gestation when the samples were taken. The stage of gestation is only approximate in each case since its beginning was calculated back two hundred and eighty days from the date of birth of the child.

An examination of the data in table 7 shows that subject S. H. had been nursing her child about fourteen months at the time she became pregnant. Between the second and third months of gestation the composition of the milk began to show the changes characteristic of advanced lactation, until at the end of three months the protein concentration had practically doubled, and the fat was much higher than the average. The child was weaned at this time because of a scanty milk flow, and because it was old enough to take nourishment satisfactorily from other sources. No unusual digestive or nutritional disturbances were reported except at the very beginning of pregnancy, when the child is stated to have been sick. The effects of gestation in the case of this lactation seemed to be merely a hastening of the close of lactation, with the usual changes in the composition of the milk characteristic of advanced lactation.

Gestation began after five months of lactation in the case of subject C. M., the data from which are shown in table 8. The observations were continued in her case through the fourth month of gestation without noting any marked changes in the composition of the milk. This is clearly shown by the data reported. No digestive or nutritional disturbances were reported. Information is unfortunately incomplete in regard to the subsequent history of this case. It is also impossible to state why the samples were discontinued after December 5, or whether the child was weaned at this time or subsequently. The presumption seems admissible that the milk flow became scanty after December 5, which would be in keeping with the effect of gestation in the case of subject S. H., but the composition of the milk does not show the effects of advanced lactation.

It is to be regretted that our data are not more extensive. They are characterized by a marked uniformity, however, and are in decided contrast to the only previous data on the subject, namely that published by Davis. The failure of clinical symp-

toms to appear as an accompaniment to gestation in either case also shows that digestive disturbances in the case of children nursed by pregnant mothers do not invariably appear, as was stated by Guida.

TABLE 8

Percentage composition of the milk of C. M. during portions of lactation and gestation periods which overlapped

TWELVE HOUR COMPOSITE FOR THE WEEK ENDING	VOLUME OF MILK	STAGE OF LACTATION	APPROXIMATE STAGE OF GESTATION	SPECIFIC GRAVITY OF MILK	TOTAL SOLIDS	TOTAL PROTEIN N. × 6.38	FAT	SUGAR
1908	*cc.*	*days*	*days*		*per cent*	*per cent*	*per cent*	*per cent*
April 9		33		1.0323	13.03	1.79	4.07	6.84
April 16		40		1.0320	12.67	1.66	3.15	7.08
April 23		47		1.0319	12.19	1.53	3.34	5.26
April 30	125	54		1.0324	13.23	1.40	3.92	6.83
May 7	105	61		1.0321	11.82	1.40	3.22	6.52
May 14	115	68		1.0322	11.40	1.40	2.82	6.50
May 21	75	75		1.0320	12.98	1.34	4.08	6.95
May 28	90	82		1.0310	12.93	1.60	3.95	7.05
June 11	100	96		1.0288	13.13	1.40	4.16	6.58
June 18	70	103		1.0314	12.42	1.40	3.69	
June 25	80	110		1.0297	12.47	1.53	3.52	7.05
July 2	75	117		1.0310	12.67	1.47	3.73	7.13
July 9	130	124		1.0306	13.00	1.34	3.97	6.90
July 16	115	131		1.0308	12.34	1.47	3.19	6.66
July 23	145	138		1.0325		1.21		6.82
July 30	75	145		1.0290	11.80	1.28	2.90	7.26
August 6	150	152	6	1.0306	12.14	1.21	3.92	7.46
August 13	105	157	13	1.0312		1.60		6.95
August 20	90	164	20	1.0303	12.81	1.21	4.09	7.76
August 27	100	171	27	1.0323	13.88		6.46	6.20
September 3	100	178	34	1.0265	12.76	1.40	4.51	6.69
September 10	65	185	41	1.0323	15.98	1.40	7.49	6.38
September 17	120	192	48	1.0293	13.65	1.66	5.18	7.24
September 24	110	199	55	1.0315	11.55	1.47	3.26	8.31
October 3	60	206	65	1.0280	14.02	1.28	5.48	7.80
October 10	100	213	72	1.0310	10.32	1.08	1.83	7.39
October 17		220	79	1.0330	10.45	1.15	2.48	
October 22	90	225	84	1.0335	11.24	1.21	2.93	6.66
October 31	80	234	93	1.0330	11.99	1.08	3.92	7.05
November 7		241	100	1.0329	11.76	1.40	3.52	7.23
November 14	65	248	107		12.22	1.15	3.82	
November 21	55	255	114		11.91	1.08	3.88	
November 28	65	262	121		12.84	1.21	4.98	6.70
December 5	65	269	128					8.13

Our data indicate that under normal conditions gestation exerts no influence on the composition of mother's milk, but that it may greatly hasten the close of lactation with the changes in the composition of the milk which accompanies it if lactation is sufficiently advanced when the period of gestation begins. The whole question is worthy of more extended study, particularly with regard to the disturbances in the health of the child which have been mentioned as accompanying pregnancy in the case of the mother. The variations in the composition of human milk, the factors which contribute to these variations, and the relation of these variations to the health and nutrition of the child have not received the attention they deserve. Similar information in regard to cows' milk is much more extensive at the present time. Many opinions regarding the extent of the variations to which the composition of cows' milk is subject, which were formerly held by many people, have been disproved, but are still regarded as being true for human milk. No doubt many of these opinions are equally unfounded for human milk, but the experimental data are not available to disprove them.

SUMMARY

Gestation of itself exerts no influence on the composition of either cows' milk or human milk, but it may indirectly affect it by hastening the close of lactation, which itself exerts marked changes on the composition of milk. The characteristics of the milk as the end of the lactation approaches are high concentration of protein and fat, and frequently a lower concentration of lactose. The fat of cows' milk is characterized by great depression of the saponification value and Reichert-Meissl number, and great increase in iodin value and melting point.

Disturbances in the health of the child being nursed by a pregnant mother were not observed in the two cases reported in this paper. The marked decrease in the percentage of all the solid constituents of the milk reported by another investigator as accompanying gestation in the case of human milk was not confirmed by our data.

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WHAT IS MEANT BY "QUALITY" IN MILK

H. A. HARDING, R. S. BREED, W. A. STOCKING, JR., AND E. G. HASTINGS

The Illinois, New York and Wisconsin Agricultural Experiment Stations coöperating

FOREWORD

For many years the Official Dairy Instructors Association, which has recently become the American Dairy Science Association, has maintained a committee on dairy score card, which committee is responsible for the so-called "official" dairy score card. In 1912 this committee recognized the necessity for a different score card evaluating the quality of milk rather than the conditions under which milk was produced, and formed a subcommittee to study this problem. This subcommittee was later made an association committee on milk quality. Extensive investigations have been conducted particularly at the New York Agricultural Experiment Station, at Geneva, and the Illinois Agricultural Experiment Station in connection with this study, and the present publication is an analysis of the problem of milk quality as it appears to this committee after these years of study.

H. A. HARDING
College of Agriculture and Agricultural Experiment Station, University of Illinois
R. S. BREED,
New York Agricultural Experiment Station, Geneva
W. A. STOCKING, JR.
New York State College of Agriculture and Agricultural Experiment Station at Cornell University
E. G. HASTINGS
College of Agriculture and Agricultural Experiment Station, University of Wisconsin

INTRODUCTION

The terms "good" and "bad" are often used to describe quality in milk. These terms, however, are indefinite and it is difficult to draw an arbitrary line of separation on this basis. It needs but a slight study of the milk question to recognize that the goodness or badness of milk depends upon several factors. Because of the complexity of this situation there is much confusion in the public thought regarding quality in milk. As a result, milk is still commonly sold without the use of grades to designate quality, the state of New York being one of the exceptions to this rule.

The present publication is a brief summary of previous considerations of the various sides of this question, a plea for a broader consideration of the problem of milk quality, and a suggestion regarding the line along which future progress in the improvement of city milk supplies will undoubtedly be made.

ELEMENTS OF QUALITY IN CITY MILK

Many factors combine to determine the quality of milk. Each of the factors has been recognized as important at one time or another, but apparently thus far no one has succeeded in so fully analyzing the city milk situation as to formulate a complete expression for milk quality. The following summary[1] of the elements of quality in city milk under the headings of food value, healthfulness, cleanliness, and keeping quality is an attempt at such an analysis. The order of presentation of these elements is essentially that in which they have been previously brought to public attention.

Food value

While milk is sometimes used as a beverage, the fundamental reason for the existence of the present vast traffic in milk is the

[1] This summary of elements of quality in city milk does not consider the occasional occurrence in milk of disagreeable substances, of which onions and gasoline are the most common examples, because the evident presence of such substances automatically excludes such milk from the city trade.

fact that milk is one of our most important foods. Not only does it offer energy in a readily available form, but the amount and variety of the compounds contained in milk make it a peculiarly valuable food for growing children. The present consumption of milk in this country is only about 0.6 pint per capita per day, although from the standpoint of protein, which is especially needed by the growing child, or from the standpoint of total energy as utilized by the adult, much more food value is obtainable from milk for a given sum of money than can be purchased in any comparable food. The following table recently prepared by the United States Department of Agriculture illustrates this point:

Protein	*Energy*
1 quart of milk is equal to:	1 quart of milk is equal to:
7 ounces of sirloin steak	11 ounces of sirloin steak
6 ounces of round steak	12 ounces of round steak
4.3 eggs	8½ eggs
8.5 ounces of fowl	10.7 ounces of fowl

In 1856 the laws of Massachusetts (2) attempted to protect milk from adulteration and since that time federal, state, and municipal authorities have enacted laws establishing standards for butter fat and the other solids in milk. It was the original conception that milk was of essentially fixed composition and that the establishment of minimum standards would stop the watering and skimming of milk. The establishment of these legal standards undoubtedly has had a pronounced effect in limiting open and gross adulteration of milk, but the secondary and unexpected effects of such enactments have been such as to raise the question whether, taken as a whole, they have been beneficial to the quality of the milk supply.

While it is true that these legal standards set definite limits to the extent to which the food value of milk could be reduced without incurring the penalty of the law, at the same time they offered indirectly stimulus for the reduction of such food value to a figure approximating these legal minimum standards.

The cost of producing milk at the farm is fairly proportional to the amount of food value in the milk. With the narrow margin

of profit which exists in milk production, there has been a strong impelling force toward the production of milk with the smallest food value that the market would accept without reduction in price. When the law prohibited the reduction of food value by the direct addition of water, the same result was frequently accomplished by the selection of animals producing milk which approached or even fell below the legal minimum limits. It is a matter of common knowledge that the milk supplies of our larger cities have been falling in food value, and today much of the milk sold in such cities is almost exactly at the legal limit of fat and below the legal limit in solids not fat.

This reduction in food value is all the more striking in view of the marked preference which the consuming public has for milk of high food value. Many progressive milk dealers recognizing this situation have offered milk high in fat content at an advanced price with commercial success.

While there is no simple, and at the same time, entirely satisfactory method of expressing the food value of milk, it may be roughly measured in a variety of ways. The housewife customarily judges the food value of milk by noting the depth of the cream line in the milk bottle. The food value of the other constituents of normal milk do not vary in absolute proportion to the fat, and therefore the fat is not an entirely accurate measure of the food value of the milk; but, at the same time, the variations in total food value are so nearly proportional to the variations in the fat of the milk that the fat content of a milk of cows may well be used as an index of the relative food value of various samples of milk. This index has the added convenience of being easily and accurately determined by means of the Babcock test.

Healthfulness

It is not enough that a bottle of milk shall have abundant cream in order to be accurately characterized as good milk. If such milk should contain even a limited number of virulent typhoid-fever organisms, it would be rejected by anyone who

was acquainted with this fact. While the milk business is conducted primarily because milk is a valuable food, the occasional appearance of an epidemic spread by the use of milk has made the public suspicious of the healthfulness of all milk. This public suspicion is a severe handicap to the milk business, and any procedure which will remove this suspicion and stimulate the increased consumption of milk will be of great economic benefit to the dairy industry as well as to the consumer.

While the possibility of milk functioning as a carrier of disease had been previously discussed, beginning about 1893 (3) the use of the tuberculin test revealed a large amount of tuberculosis in dairy cattle and the public was impressed with the danger of spreading tuberculosis through the milk (4). Later investigations, particularly those made during the past fifteen years, have fully demonstrated the danger of tuberculosis being transmitted from cows to children through the milk. Occasional epidemics (5) of septic sore throat and typhoid fever and less frequently epidemics of scarlet fever and diphtheria transmitted in the same way have given good grounds for suspicion regarding the healthfulness of the ordinary raw milk supply. The amount of danger from this source is commonly overestimated, but its existence, particularly in the case of children, is beyond question and should not be overlooked.

Health authorities, early recognizing tuberculosis of cattle as a public menace, attempted to stamp it out by the widespread application of the tuberculin test. The difficulties encountered in such an attempt made it evident that whatever may be the value of the tuberculin test as such, there is little prospect that the application of the test will become so widespread as to offer protection to the general milk supply.

It has also been recognized that tuberculosis is only one of a number of diseases which may be distributed through the milk supply. Any plan which is to make milk a safe article of food must take account, not only of diseases which may be transmitted from the cow, but also of the more formidable list of diseases which may be transmitted by the milk from the people who handle it to those who consume it. The history of certified

milk has made it evident that a careful medical supervision of both animals and men will reasonably protect the milk from danger of transmitting human diseases, but the expense of such supervision is large.

Pasteurization of milk was early advocated as a means of safeguarding the consumer from the dangers, not only of tuberculosis, but of other transmissible diseases. As with the tuberculin test, so with pasteurization, many practical difficulties were encountered in applying the process to the milk supply.

The studies of Theobald Smith (6) and of Russell and Hastings (7) which pointed out the practicability of pasteurizing milk at 140°F. for thirty minutes, mark the real beginning of modern successful milk pasteurization. This pasteurization, which both gives the desired protection against disease germs and furnishes a product satisfactory to commercial milk requirements, was the beginning of a widespread general interest in the subject. This interest has grown to the point where the regulations of the largest cities and of some of the smaller cities make such pasteurization of the general milk supply compulsory. In some instances this movement toward pasteurization has even taken the form of state enactment (8).

It is evident that if the milk supply is to be made so safe as to banish the suspicion of danger from disease germs, which is now a factor limiting the consumption of milk, the milk must either be produced under a careful medical supervision regarding the health of the cows and men or it must be properly pasteurized.

Cleanliness

In order to conform to the general opinion of a good milk, it is not sufficient that a milk shall have high food value and shall be free from danger of disease. If at the bottom of the bottle of milk there is a distinct sediment, the purchasing public will uniformly reject the milk as being of poor quality. The public is justly desirous of having a clean food supply, and there is probably no food product regarding which it is more sensitive than milk. The extreme sensitiveness of the public in this matter is due in part to the fact that milk naturally lends itself to careful

inspection. The white milk forms a natural background against which any foreign matter stands out with startling distinctness. As a result of these physical conditions the unaided eye is able to detect the presence of foreign matter in milk when it is present in such minute quantities as to practically defy detection by analytical methods. The sensitiveness of this inspection is shown by the fact that it is possible to thus find traces of foreign matter in practically any quart of milk which is critically examined, regardless of the care exercised in its production. In the certified milk from the cleanest dairies in the country which is annually brought together in competition at the National Dairy Show, such foreign matter is evident to the eye in over 80 per cent of the bottles. On the other hand, the amount of this foreign matter is so slight in all certified milk, and in practically all commercial milk, as to be upon the very margin of detection by analytical methods.

Taking advantage of the sensitiveness of the eye to differences in color, a method called the sediment test (9) has been devised for determining the cleanliness of milk. In applying this sediment test, measured quantities of milk are passed through cotton and the dirt is observed as a residue upon the white cotton. This test has been quite widely applied in commercial work. While in rare cases the presence of considerable amounts of dirt has been demonstrated, in practically all instances the amount of dirt found in the milk has been slight. When attention has been directed to the presence of any considerable quantities of dirt, the conditions of milk production have been promptly modified so as to bring the milk to a uniformly high standard of cleanliness.

Milk as it is now generally produced and handled is one of our cleanest foods.

Keeping quality

In order that a milk shall be justly entitled to be called good milk, it is not sufficient that it be high in food value, that it be free from danger of carrying disease, and that it be clean, because if it is sour when delivered to the consumer or sours promptly

thereafter, it is unsatisfactory. In the northern states, at least, the delivery of milk once a day is expected to supply the needs of the family for the succeeding twenty-four hours. Accordingly, good milk must remain sweet during that period, and preferably during a longer period, in order to justly entitle it to be called good.

It is possible to estimate the condition of the milk with regard to food value, healthfulness, and cleanliness, by comparatively simple methods. The situation with regard to keeping quality is more complex. Souring is induced by the growth in the milk of minute forms of plant life—bacteria. This plant life attacks the sugar of the milk, using it as a food, and producing acid as a by-product. When the accumulation of this acid amounts to approximately 0.3 per cent, the milk begins to taste sour; and when the accumulation of acid has reached approximately 0.7 per cent, the milk curdles. The problem of maintaining a satisfactory keeping quality is essentially a problem of restricting the development of germ life. It is possible to meet this problem either by preventing the entrance of germs, by destroying them after they enter, or by holding the milk under conditions which will prevent the activity of the germs after they enter.

While the problem of the keeping quality of milk can thus be stated in simple terms, the actual restriction of contamination and of development of germ life is a complex matter. There is still a lack of knowledge regarding the relative importance of the various avenues through which bacteria gain access to the milk, and this results in a lack of knowledge regarding the most practicable means of preventing their entrance.

In attempting to control keeping quality, various cities have made regulations establishing a maximum number of germs permissible in their milk supplies (10). These regulations did not attain the desired results, and in many cases the cities further stipulated various conditions which must accompany milk production. The establishment of bacterial standards placed upon the milk producer and the milk dealer the responsibility of translating these standards into terms of dairy processes, while the detailed recommendations formulated by the health authorities

are an attempt on their part to make this translation. In practice both these attempts have failed to accomplish the desired end. As a measure of the keeping quality there are many advantages in a direct (11) determination of the germ life, but this is a technical process not readily available to the dairymen and accordingly has certain limitations.

The true measure of the keeping quality of milk is the time which elapses before it actually sours. This is the measure employed by the consumer, but manifestly it cannot be applied in advance at any earlier stage in the commercial life of the milk. A modification of this is possible in that samples of the milk under consideration may be held at high temperatures and the interval before curdling noted. From a comparative study of the effect of a temperature on germ growth, it would then be possible to translate this interval into the time which would elapse before the original milk would sour at the lower temperature at which it would normally be held. This procedure involves some time and technical apparatus which is not often available.

The commercial milk men have long employed the acid test, as well as their trained sense of taste and smell, in estimating the probable keeping quality of milk as delivered at their plants. By these means they have been able to anticipate somewhat the time at which milk will be no longer acceptable to the whole-milk trade, but it is only as milk approaches this limit that its condition is determinable by these means.

During the past few years there have been suggested a number of technical milk tests more or less closely related to keeping quality, such as the reductase test, the Schardinger reaction, the alcohol test, the catalase test, and the hydrogen ion concentration. In general the availability of these tests seems limited because they are mainly useful only in the later stages of the commercial life of milk.

In view of this unsatisfactory condition of knowledge regarding the measurement and control of the keeping quality of milk, the New York (12) and Illinois (13) Agricultural Experiment Stations have undertaken extended and detailed study of the

various factors affecting the entrance and growth of germ life in milk.

Complexity of the problem

The above outline of the various phases of milk quality brings out the fact that at various times the students of the milk question have been interested first in one, then in another element of milk quality, and that in connection with each such attempt they have succeeded in devising a more or less successful index of quality with regard to the particular point under observation.

This publication is designed to emphasize the fact that the quality of city milk is not a simple matter to be adequately expressed after a consideration of any one factor, but that it is a complex matter which can be expressed only after an adequate consideration and evaluation of each of these four essential factors; namely, food value, healthfulness, cleanliness, and keeping quality.

While the percentage of fat in milk is not a perfect measure of the food value, it is an easily determined index of food value. While medical supervision of the health of the cows and the men or proper pasteurization are not absolutely self-sufficient guarantees of the healthfulness of milk, they are the most practicable and easily applied indices of healthfulness. The sediment test, while open to some objections, is a simple and easily applied index of milk cleanliness. The problem of a satisfactory index for keeping quality is not so simply solved. Among the many available tests, that one must be selected which will best suit the purpose in hand.

Much of the confusion in the public mind regarding milk quality has been due to a failure to discriminate properly between germ content and healthfulness, on the one hand, and germ content and cleanliness, on the other.

The introduction of the public to the subject of germ life came through the attention which was early given to germs as producers of diseases such as tuberculosis (14) and typhoid fever. To the public, bacteria and disease became practically synonymous words. Later the attention of the public was directed to

germ life in milk (15) at about the same time that its attention was directed to the possibility of germs of tuberculosis (16) being present in milk. Therefore, it is not at all strange that in public thought germ life and unhealthfulness of milk should have seemed identical.

Early in the present century Metchnikoff (17) and other writers began to lay stress upon the health-giving qualities connected with certain germs in milk, as those of the Bulgaricus group. More recently extensive commercial use has been made, not only of cultured milks of various kinds, but also of vast quantities of buttermilk containing the ordinary sour-milk organisms with or without the addition of cultures of the Bulgaricus forms. There is a continued satisfactory use of these sour-milk drinks which contain many millions or billions of bacteria per cubic centimeter, not only of these special organisms with foreign names, but also of the organisms present in our sour milk of commerce. These experiences are gradually bringing home to the public an appreciation of the fact that there is very little connection between the amount of germ life in milk and the healthfulness of milk.

The confusion in the public thought between the presence of germ life and cleanliness of milk arises from the fact that it was originally believed that the seeding of milk with bacteria came about primarily as a result of a large quantity of bacteria being carried into the milk upon various forms of foreign matter, such as dirt and dust. Each particle of dust in the barn air was looked upon as an omnibus overloaded with attached germ life.

More recent studies have shown that dust particles, instead of being loaded in the manner described, actually carry living organisms in less than one case out of a hundred.[2] While it

[2] Compare, for example, the number of dust particles per cubic foot of air as reported on page 61 of Final Report of the Committee on Standard Methods for the Examination of Air (Am. Jour. Pub. Health, vol. 7, pp. 54–72, 1917), where the number of dust particles per cubic foot of the air of New York City streets is given as between 400,000 and 1,000,000, as determined by the filtration method, with the number of bacteria per cubic foot of air as reported by Winslow, C. E. A., and Browne, W. W. (The microbic content of indoor and outdoor air. Monthly Weather Review, vol. 42, pp. 452–453, 1914). The average numbers of bacteria which the latter authors report do not exceed 113 per cubic foot for air from the open country, from city streets, from offices, from factories, and from schools.

is true that a small number of germs are carried into the milk upon dirt, the amount of dirt actually finding its way into the milk is so small in proportion to the mass of the milk that the germ life added in this way is relatively insignificant. The confusion regarding bacteria in milk is being cleared up by studies which show that the real source of contamination of milk is either an unusual population of bacteria in the udder, or far more frequently, the presence of a surprisingly large amount of germ life upon the utensils in which the milk is handled. So persistent is this idea of the constant association of germ life and dirt that the natural inference would be that utensils carrying large numbers of germs were dirty. This inference is not in accord with the carefully observed facts, since germ life is present in vast numbers upon dairy utensils which have been rendered clean in the ordinary sense of the word, but which have not been so handled as to obliterate germ life.

Later studies of germ life in the udder (18) have made it plain that germ life is constantly present in all samples of normal milk from the time it is secreted by the glands of the udder to the time it is utilized by the consumer.

Too frequently the public thinks of milk merely as a fluid containing butter fat, while it should of course recognize the fact that milk also normally contains about 5 per cent of milk sugar, as well as varying amounts of other nitrogenous substances which become most prominent in such things as cottage cheese. Until a few years ago, few people appreciated that in the process of milk secretion, worn-out gland cells and blood corpuscles are thrown off into the milk and form a part of normal milk, since they are uniformly and regularly present in considerable numbers in all milks (19). The recentness of our appreciation of the normal presence of these cells in milk is shown by the fact that up to a few years ago in certain cities there existed regulation forbidding the presence of what are now known to be fairly normal quantities of these cells in milk.

While the public is generally aware of the fact that milk always contains considerable quantities of germ life, it has probably not yet come to appreciate the fact that germs in milk are just

as constant, and therefore just as normally a part of milk, as are milk sugar, fat globules, and body cells. The consumer has little interest in the germ content of milk except for a limited number of disease-producing forms against which he has a right to insist upon adequate protection, and except in so far as the germ life produces objectionable changes such as souring or bad flavors in the milk itself.

COMPOSITE EXPRESSIONS OF QUALITY

As has already been stated, the students of milk have recognized more or less distinctly the various elements of milk quality. However, the public mind insists upon a simple, direct statement of quality regardless of the complex relationship involved. It insists that a milk must be *good*, *medium*, or *bad*. Various plans have been devised for meeting this demand and furnishing a composite expression for milk quality.

Certified milk

Certified as applied to milk, signifies that it has the food value of normal 4 per cent milk, the healthfulness resulting from a careful medical supervision of all animals and men connected with the production and handling of the milk, the cleanliness following careful attention to the cleanliness of the animals and the utensils, and the keeping quality to be expected of fresh milk with a low germ content, kept at a very low temperature.

Score card

As a measure of the desirability of the ordinary milk supply, various dairy score cards have been suggested. These score cards are an attempt to express on a percentage basis the protection given milk on the farm from the danger of contamination with disease-producing germs both from animals and from men (healthfulness); the protection given milk from dirt (cleanliness); and the protection given milk by care of utensils, by cooling, and by prompt delivery (keeping quality). These score cards have uniformly failed to take account of the food value of the milk. Since these score cards are arranged on the basis of the

agricultural methods and equipment rather than on the basis of the milk, it is but natural that in the cards themselves there should be much confusion regarding the items which apply respectively to healthfulness, cleanliness, and keeping quality. Some have expected to find correlation between germ content and the dairy score; others feel that there should be a correlation between cleanliness of the milk from dairies and the dairy score: while others expect a correlation between the score of the dairy and the presence or absence of disease germs. Such comparisons on the basis of a single element of quality are necessarily unfair to the score card unless it is recognized that the dairy score combines factors connected with all three elements of quality.

The essential difficulties of present score cards arise from the fact that they are an attempt to evaluate the influence of dairy environment and processes upon the milk, when the relative importance of such factors has not yet been sufficiently determined.

Grade.—This presentation would be very incomplete if it did not include a suggestion as to the manner in which the four elements of milk quality herein discussed might be combined so as to form a basis for defining grades of milk. The following is offered as a suggestive outline rather than as a finished plan for milk grading:

Grade	*Element of quality*	*Degree of excellence*
Special milk	Food value	Fat content as stated on package
	Healthfulness	Medical supervision of health of men and animals, or proper pasteurization
	Cleanliness	Sediment, not more than a trace
	Keeping quality	Excellent
Table milk	Food value	Fat content as stated on package
	Healthfulness	Properly pasteurized
	Cleanliness	Sediment, not more than a small amount
	Keeping quality	Good
Cooking milk	Food value	Fat content as stated on package
	Healthfulness	Boiled
	Cleanliness	May not be sufficient for table grade
	Keeping quality	May not be sufficient for table grade

Under the grade of *special milk*, the plan provides for milk of any desired composition to meet any special need, such as baby feeding. The grade of *table milk* will normally include the ordinary city supply. The grade of *cooking milk* is designed for milk not sufficiently fresh or not carefully enough handled to be suitable for the table grade. In order to assist in protecting the consumer from unwittingly purchasing cooking milk instead of table milk, it is suggested that cooking milk be boiled. Such treatment will adequately protect healthfulness, and while making this grade of milk readily recognizable, will not injure it for the use for which it is designed.

RESPONSIBILITY OF THE PRODUCER FOR MILK QUALITY

If the foregoing analysis of milk quality is correct, the producer sustains somewhat different relations to each of the elements of milk quality than has been ordinarily supposed. Contrary to current belief, he is unable to control food value to any appreciable extent by his method of feeding the cow. The forces of heredity have determined what shall be the composition of the milk of a given animal, and except for slight seasonal variations or local disturbances a cow persists in giving milk of essentially a fixed composition. On the other hand, by selecting his animals he is able to produce milk of widely different food value, but at a correspondingly different cost of production. Manifestly, it must be expected that he will produce a milk having a food value which will give him the widest margin of profit.

In the matter of healthfulness, the producer has the responsibility of protecting, in so far as he is able, the milk supply from contamination by disease-producing organisms derived either from cows or people. His recognized inability to satisfactorily protect milk in this way calls for the added protection of medical supervision of the health of the cows and men, or of pasteurization; but medical inspection and pasteurization are, manifestly, not the producer's problem.

The element of cleanliness is largely in the control of the producer. Under present economic conditions, he is producing a milk with a very high degree of cleanliness, and if any additional

stress is laid upon this point he will undoubtedly produce milk which is uniformly very clean.

The element of keeping quality is the one which presents the greatest practical difficulty, because here the responsibility is much divided. Definite information regarding many details is still lacking, but the present stage of knowledge suggests that the most common contributing factor to poor keeping quality is the condition of the milk cans which are supposed to be properly treated at the milk plants. Where milking machines are used, they are very frequently a large contributing factor to the short keeping quality of the milk.

The adoption by the producer of the uniform practice of rinsing his milk utensils with scalding hot water shortly before they are used, would contribute very much to the keeping quality of the milk. In practice each utensil coming into contact with the milk adds to its germ content and decreases its keeping quality. A reduction of the number of such utensils to the minimum is very desirable.

Under ordinary conditions the udder of the cow contributes but a small number of germs and these have little effect upon the milk. Occasionally, however, cows or even herds are found where the udder content is high and the effect upon the keeping quality of the milk pronounced. Further information is necessary before the true significance of this factor can be accurately estimated.

RESPONSIBILITY OF THE DISTRIBUTOR

The responsibility of the distributor in the matter of food value concerns itself essentially with conserving the food value of the milk as furnished him by the producer. Where economic conditions permit, he is able to stimulate the production of milk with a higher food value by paying a differential price.

For the healthfulness of milk a heavy responsibility lies upon the distributor, particularly when he is charged with its pasteurization as a final safeguard to the consumer. As a possible source of disease-producing germs, human beings are more dangerous than cows, and a medical supervision of the employes

of the milk plant is desirable. This is particularly important in the case of milk pasteurized in bulk, since this process gives no protection from the later contamination, which is a more or less remote possibility during the cooling and bottling processes.

The milk as it comes from the producer usually is and always should be clean. The problem of the distributor is to preserve this cleanliness.

The keeping quality of milk is more largely within the control of the distributor than is usually supposed. He is frequently responsible for the washing and steaming of the milk cans. Where this steaming is done in a perfunctory manner, particularly where tight-fitting covers are applied to wet cans in warm weather, these cans become one of the most important factors in reducing the keeping quality of the milk. Where a proper washing of the cans is followed by a thorough steaming and the cans are carefully dried before being covered, they will have little objectionable effect upon the milk. The large germ content added to milk by utensils within the distributor's plant is frequently an important factor in impairing its keeping quality. The milk coolers and the bottling machines require special watching in this connection, not only because they frequently add large numbers of germs, but especially because they add them *after the milk has been pasteurized.*

The intelligent application of steam to all of the utensils should be a routine procedure, and the flushing out of all utensils with scalding water shortly before using them is a valuable additional precaution.

RESPONSIBILITY OF THE CONSUMER

The food value of the milk furnished the consumer will depend primarily upon what the consumer desires and is willing to pay for. A considerable proportion of the consumers are desirous of obtaining a milk carrying 4 per cent of fat or more, and where the milk has been sold regardless of food value they have striven to find the richest milk available at a given price. If each bottle of milk carried a statement of its fat content, the responsibility

would then be upon the consumer to recognize and pay for increased food value.

The consumer through his agents, the health officials, must determine how the healthfulness of the food supply shall be safeguarded. The dangers which naturally surround milk production and handling are such that if the milk supply is to be safe it must be protected either by a medical supervision of the health of the cows and the men or by proper pasteurization, or better, by a combination of both means of protection.

The cleanliness of milk, as it is now delivered to the consumer, is in general very satisfactory, but continued emphasis is needed to insure that it shall be constantly maintained at a high level.

The keeping quality of milk is constantly receiving the attention of the consumer, since there is no other shortcoming of milk which is more quickly impressed upon him. The delivery to the consumer of old, stale milk, on the verge of souring is quite as much a fraud as the delivery of milk deficient in food value, healthfulness, or cleanliness. The consumer is constantly insisting on improvement in keeping quality, and his desires will be met as rapidly as the producer and the distributor find economical means of insuring this improvement.

Since the keeping quality of milk after delivery is dependent primarily upon the temperature at which the milk is held, the responsibility rests upon the consumer to hold the milk at a reasonably low temperature after it is delivered to him. Too frequently little regard is given to this matter by the consumer, and much of the criticism directed against the keeping quality of milk is accordingly unjust.

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CONCERNING RANCIDITY OF BUTTER

E. S. GUTHRIE

Department of Dairy Industry, Cornell University

INTRODUCTION

Rancidity is a specific flavor of dairy products. It is a term that is usually used erroneously. The average person confuses it with the *strong* or the *stale* flavor, or some other "off" flavor of butter. Butter is even described in faulty terms by the federal law, when it says "non-rancid product," for undoubtedly what is meant is the *strong* flavor.

The rancid flavor of butter is not a general one. It is not the flavor that is described below. Brown (1899) defines it thus, "By the term 'Rancidity' is meant not simply as is generally supposed, a development of free acid, though this is the general concomitant of rancidity, but any chemical or physical change in the character of the fat from the normal. Rancidity, according to the present most commonly accepted understanding of the term is simply oxidation." Rahn, Brown and Smith (1909) say, "Butter is said to be rancid if it has an undesirable taste or smell, due to an aged condition, that cannot be described definitely by other terms."

The author maintains that the butter judge is the only person who is in position to determine rancidity of butter. The above mentioned men have done a great deal of research which the author wishes he might call scientific. Inasmuch as they did not build their work on a good foundation, or in other words, so long as they did not get a butter judge of repute to put them straight at the beginning, their works are absolutely worthless to the dairy world and they are of interest only as showing chemical changes. The following letters from White (1910) and Kieffer (1910) who are among the best butter judges of America,

show that rancidity of butter is not a general term but that it is very specific. White (1910) says:

> If the student is given some stale tallow and told that it is rancid and then is given some stale lard and told that it is also rancid, he will be able to distinguish that the smell is not the same. If he is then given some butter which has developed a butyric acid odor he will find still a different odor, and the question would naturally be asked which of the three is and should be defined as rancid. If the odors found in the tallow and lard are rightly defined as rancid then the butyric acid odor in butter known by all butter judges, commission men, butter buyers, buttermakers and dealers in general, should be called something else as they are not the same, though that found in butter may be called rancid as a general term, meaning stale, but specifically it perhaps should be called butyric odor. The butyric odor gradually passes off since it is volatile, but there will then still remain a stale odor, and this will smell like stale tallow. On the other hand, if the butyric acid odor is the true rancid odor then the odors found in other fats and oils should not be defined as rancid.

Kieffer (1910) in answer to a letter asking for a definition of rancidity says, "I usually use that term on butter when it has an over sour strong flavor." The author once showed Mr. Kieffer some distillate of the Reichert-Meissl number, and asked if he would call it rancid. Kieffer's reply was that it resembled the rancid flavor a great deal. The distillate of the Reichert-Meissl number of butter contains the volatile fatty acids among which is butyric acid. Probably Mr. Kieffer got only enough of the butyric acid odor to make him think that it was slightly rancid. The author and many of the butter judges with whom he has conferred think that the rancid flavor of butter can best be obtained by a weak diffusion of butyric acid in the air. A small amount of butyric acid gives the characteristic flavor of rancidity. A strong solution of butyric acid does not give so characteristic a flavor of rancidity as may often be found in butter, for this acid is not found in large quantities in butter. The author knows rancidity in butter as a butyric acid flavor.

REVIEW OF PREVIOUS STUDIES ON RANCIDITY, SOME OF WHICH WERE PROBABLY NOT STUDIES ON TRULY RANCID BUTTER

What are the causes of rancidity and is there a measure for it? Stockmeir evidently considered that there was a direct relation between the free acid and rancidity for he introduced the so-called "Degrees Rancidity" which represents the number of cubic centimeters of normal alkali required to neutralize the free acid in 100 grams of fat. Amthor (1899) says, "It has hitherto not been found possible to give numerical expression to the degree of rancidity." After a review of his own research, Amthor concludes, "It would seem that the proportion of ethylic butyrate and volatile fatty acids should be employed as the criterion of rancidity." Richmond (1899) wrote, "The action seems to be hydrolysis of the fat, splitting it up into fatty acids and glycerol; the latter perhaps is not liberated as such, but is oxidized, yielding aldehydes and acids of butter; the volatile acids are liberated and the smell of these can be detected in rancid butter." Corbetta (1891) observed that there was a reduction in the quantity of volatile fatty acids. He concludes, "The disappearance of volatile fatty acids in the rancid butter, although progressive in these experiments was in no instance very considerable." Rahn, Brown and Smith (1909) say, "We had butter without the slightest increase of acid which scored 'very rancid.'" Schmid (1893) asserts, "The acidity of a fat is not as was formerly assumed a measure of its rancidity . . . . it is rancid when the glycerol has undergone partial or complete oxidation to aldehydes and keytones." Spaeth (1896) wrote, "Although the most divergent views have been put forward with regard to the cause of the development of rancidity in fats, the more recent researches (those of Duclaux, Risert and Van Klecki) have demonstrated conclusively that the process is one of oxidation by the oxygen of the air and that it is favored by access of light." After a short discussion of his research on olive oil, pigs fat, and butter, Scala (1897) says, "It is therefore concluded that rancidity depends alone on the oxidation of oleic and other acids of that series." Hagemann (1883) wrote:

The peculiar smell and taste of rancid butter is generally assumed to be due to the presence of free butyric acid . . . . . either it arises from butyric fermentation at the expense of the lactose or glycerol or else is the product of chemical changes and is set free from certain glycerides in the butter. From these facts the author concludes that the rancidity of butter is not due to butyric fermentation.

Hagemann then studied the effects of lactic acid in butter. He adds,

Fresh butter when mixed with lactic acid becomes rancid very quickly, and at a temperature too low for the growth of bacteria. Pure butterfat was dissolved in ether, a few drops of lactic acid were added and the whole allowed to stand over night. The ether was then driven off at a low temperature and the residual fat proved to be strongly rancid. . . . . These results indicate that the rancidity of butter is due to the formation of lactic acid by a process of fermentation from the milk sugar contained in the butter.

Reinmann (1900) studied along similar lines and found that light, warmth, or air, or all of them does, not or do not cause rancidity in sterile butter but it may become tallowy. He claims that ordinary cream under the same conditions may become rancid. He says that the length of time required for rancidity to develop, bore a relation to the casein and milk sugar content of the butter. Butter having a high casein and milk sugar content develops rancidity more quickly under the same conditions than butter with a low content of these two constituents. All of the organisms in several butter samples were isolated and studied for rancidity by being carefully inoculated into sterile cream which was churned into butter under sterile conditions. The butter was then stored. Reinmann reports that on examination many samples had produced high acidity and tallowy flavors, but that there was not a single case of rancidity.

Jensen (1902) studied the organisms of butter along the same lines as those of Reinmann. He isolated all of the organisms from butter that would grow and cultivated them separately and in mixed cultures in sterile butter. In some instances he

was able to obtain rancidity. Several species of liquefying bacilli, among them being B. fluorescens liquefaciens, were found. B. prodigiosus, sarcina, oidium lactis, torulae, and certain actinomycis produced high acidity in butter and in mixed cultures produced rancidity. He agrees with other investigators that acidity and rancidity are different and that they are caused by organisms.

Rogers (1902) did not find an organism that produced a marked splitting of butterfat. In 1904 he reported one torulae which had a weak lipolytic power. He added disinfectants to the same butter and was still able to observe a lipolytic action. This same butter when heated did not show changes and did not become rancid. He suggests that the lipolytic enzymes may have been present in the milk in the cow's udder, and that the combined action of these enzymes and the organisms already in the butter may have caused the formation of the free fatty acids and the rancid flavor. Rogers (1909) found that over-working butter churned from high acid cream produced a fishy flavor. He considered that the immediate cause was the oxidation of the acid. According to Reitz (1906) the organisms that split the butterfat to the greatest extent were Oidium, Mucor, B. fluorescens liquefaciens, and several species of Saccharomyces. Two sets of butter samples were studied. One set of thirty-three samples was placed in the incubator for about 600 days at 37°C., the other set was put in the ice box for about 600 days. All the samples became rancid.

It seems to be generally considered that rancidity is caused by the formation of volatile fatty acids and it is noticeable that the butter judges consider that there is a direct relation between the butyric acid and the rancid flavor. The author feels that if the names of reputable butter judges were mentioned in connection with many of the above accounts, the information would be worth many times more than it is. The reason is this: In the minds of the people in general any "off" flavor of butter can be classed as rancid. In reality in the twelve years of experience in teaching butter-making and in the study of butter, the writer has examined not more than six samples that

were really rancid. So long as rancidity is so rare a flavor it may be considered that in at least a few of the above accounts the flavor that was studied was not rancidity.

There are two possible sources of butyric acid in butter. First; the hydrolysis of the milk sugar into galactose and dextrose and then into lactic acid and also the further reaction, namely, the formation of butyric acid from the lactic acid. Secondly: the splitting of the butyrin into glycerol and butyric acid. Swithinbank and Newman (1903) say,

> The discovery of the true state of the cause was made in 1861 by Pasteur, who showed that two successive processes are here involved. First, the conversion of sugar into lactic acid as calcium lactate and afterwards the transformation of the lactate into butyrate. He demonstrated that each of these changes is due to a special ferment; in the first place the lactate ferment, in the second place the butyric ferment. . . . . Butyric acid is to be regarded in some ways as an end product of a long series of fermentative changes.

Maass (1909) sums up very pertinently the work done in his laboratory in these words, "All of these experiments seem to show that rancidity does not progress rapidly from purely chemical or physical causes." It would seem from the above discussions that rancidity is fundamentaly due to a biological cause.

RESEARCH

The plan of research was outlined as follows: Is rancidity due to chemical, cow enzymic, or biological changes? On account of lack of time to study all the factors, the first two changes were the only ones investigated. So long as most of the previous investigators thought that oxidation was the main consideration in the development of rancidity, the chemical changes were studied with especial reference to the iodine number.

Description of the aspirating apparatus

The air passed through a potassium hydroxide solution (specific gravity 1.35) to remove the carbon dioxide before

the air reached the cream. The purpose of eliminating the carbon dioxide before it was drawn into the cream was to make it possible to determine whether bacteria might be growing in the cream; if bacteria did grow, it would probably be apparent by fermentation, in which case carbon dioxide would be given off. The presence of carbon dioxide was detected by the formation of barium carbonate in the barium hydroxide bottle through which the air passed after leaving the cream. Again it was desired to eliminate the carbon dioxide because of unknown reactions that might take place if it were present. In order to prevent the carbon dioxide from sucking back through the pump, a bottle of potassium hydroxide was placed between the cream and the pump. A trap was also placed between the last mentioned bottle and the cream to prevent the barium hydroxide from sucking back into the cream. With the carbon dioxide taken out of the air it was considered pure oxygen so far as this experiment was concerned. The carbon dioxide free air was delivered slowly and continuously in the bottom of the bottle so that it bubbled up through the cream, thus coming in contact with the various constituents of the cream. Rubber stoppers were used in all bottles, and rubber cement was used in all the rubber tubing and joints to insure the exclusion of the air. The bottles were kept at room temperature (70°F). Each set was allowed to stand at least three weeks. Then each sample was plated again to determine whether contamination had taken place. Of twenty samples, only eight remained sterile. Table 1 shows the results.

The effect of bringing oxygen in contact with the fat

By use of a filter pump, air was aspirated through sterile cream which tested 32 per cent fat. The cream was sterilized intermittently in a steam chest at 145°F. for thirty minutes. This of course killed both bacteria and enzymes. Cotton was placed in the ends of the glass tubes to exclude bacteria, as the air was sucked through the cream. At the end of thirty hours each set was plated to determine whether or not the samples of

cream were sterile. All sets that showed contamination were discarded.

The flavor of the cream was criticised by Prof. W. A. Stocking, Jr., Mr. H. L. Ayres and the author. All were members of the Department of Dairy Industry at Cornell University.

TABLE 1

The effect of circulating air (CO_2 free) through cream sterilized by heat

SET NO.	TIME	BOTTLE	WHAT WAS DONE	REICHERT-MEISSL**	ACID NO.††	IODINE NO.‡‡	REMARKS
	days						
I	20	0	Fresh*	24.85	0.96	42.71	
		1	Asp. O†	26.47	1.37	43.55	Flavor of rubber and KOH
		3	Asp. O†	23.09	0.96	42.92	Bitter
		4	Check‡	24.70	0.94	42.41	Slightly unpleasant
II	28	0	Fresh	25.07	0.85	45.09	
		2	Asp. O	24.51	0.92	45.23	Rubbery and cooked
III	35	0	Fresh	25.22	0.85	41.17	
		1	Asp. air§	25.42	0.85	41.60	Bitter
		4	Check	24.11	0.75	41.30	A little rubbery
		5	Check	24.13	1.04	41.37	A little rubbery
IV	56	0	Fresh	24.48	0.70	40.73	
		1	Asp. air	23.53	0.65	40.57	Trifle rubbery

* The fresh samples were analyzed after sterilization.

† "Asp. O" = Aspirated oxygen through.

‡ "Check" = Through which no oxygen was aspirated.

§ In the last two sets the air was not filtered through KOH.

** Measure of volatile fatty acids. Method described in Food Inspection and Analysis, Leach, 1911.

†† Measure of total acid. Method described in Food Inspection and Analysis, Leach, 1911.

‡‡ Measure of oxidation. Hübls method, Food Inspection and Analysis, Leach, 1911.

It will be noticed, First: There was not a rancid sample. Second: Very little change took place in any of the constants.

The relation of enzymic development in cream to rancidity

It was the purpose of the author to study only the effect of the cow enzymic development. However, because of the difficulty

of securing milk entirely free from bacteria and their enzymes, cream was used which did not contain a large number of bacteria. Had rancidity developed, the author would have taken the next step and have studied the cow enzymes alone.

Outline of experiment

Bottles were connected as in the former experiment. Instead of killing the bacteria by heat, their growth was held in check with chloroform. Harding and Van Slyke found that bacteria did not grow in a 2.5 per cent chloroform solution in normal milk, and that the enzymic development was not affected. Some spores or possibly none-spore bearers, however, were not killed, for there were some colonies on the plates from the chloroformed cream. In order to maintain a uniform content of chloroform, the aspirated air was sucked through chloroform. It was placed in the first bottle, which in the previous experiment contained potassium hydroxide. In the other bottle was placed about a tenth normal solution of potassium hydroxide instead of a stronger one.

Results of experiment

First set. In this set of ten bottles only four went through the period of twenty-nine days without contamination. In these four bottles there was no sign of rancidity. The method of determining rancidity was suggested by Prof. G. W. Cavanaugh, of Cornell University. It consisted in evaporating the tenth normal alkali solution through which the air that contained the possible rancid products was aspirated. The solution was heated until it was fairly concentrated and then a few drops of sulphuric acid were added to liberate any possible rancid products.

Second set. Every bottle of this second set was contaminated with micro-organisms.

Third set. This last set was handled in a different way. Thirty Erlenmeyer flasks each containing 100 cc. of cream (32 per cent fat) were set in an incubator at 70°F. Each flask was tightly plugged. At the end of the given time the outlet glass tube was connected quickly with the tube leading into a bottle

containing a small amount of tenth normal potassium hydroxid solution. Suction was obtained by the use of the filter pump as in the former experiment. During the aspiration which was allowed to continue for about thirty minutes, the cream flasks were suspended in warm water and also shaken a number of times; the purpose being to aid the rancid products, if any, to pass from the cream.

Of the thirty flasks in the third set, only seventeen remained uncontaminated. The following table shows the results.

TABLE 2

The effect of the development of enzymes in cream on the iodine number in which the bacterial growth was held in check by chloroform. Also the relation of enzymes to rancidity

SAMPLE NO.	AGE	NUMBER OF BACTERIA	IODINE NO.	RANCID
	days			
Fresh		4,150	39.54	
1	35	133	35.42	No
2	35	200	36.60	No
3	38	50	38.18	No
4	38	116	38.64	No
5	38	416	39.22	No
6	42	800	37.81	No
7	45	150	35.09	No
8	45	300	35.44	No
9	45	366	35.52	No
10	45	300	35.47	No
11	47	533	34.42	No
12	47	350	39.03	No
13	53	66	39.15	No
14	53	66	38.45	No
15	53	33	38.52	No
16	53	33	37.61	No
17	53	133	39.13	No

This table shows no rancidity. The average decrease in the iodine number was 1.3. A note should be made here of the difficulty experienced in getting the fat for the final determination. First, the chloroform had to be driven off, which required at least five hours in the drying oven. The question might be asked: Did this heating have any effect on the determination? In answer, the writer has no data to submit.

Chemical changes resulting from the effect of light, air and temperature on butter and milk fat

Brown (1899) writes, "The three factors most active in the production of rancidity in fats are (1) openness to air, (2) exposure to light, (3) degree of warmth." In the following table he gives some interesting figures on milk fat which according to his definition became rancid.

TABLE 3

Table XII of Brown (1899)

	ACID NO.	REICHERT NO.	IODINE NO.
Fresh	0.48	15.63	34.95
One week	1.28	15.80	34.55
One month	10.90	17.00	28.40
Two months	28.84	18.75	14.35
Four months	30.00	19.80	11.15
Eight months	35.38	21.13	8.55

There was a great increase in the acid number, a noticeable increase in the Reichert number and a marked decrease in the iodine number.

Corresponding results are found in table 4.

TABLE 4

Table XIII of Brown 1913*

		ACID NO.	IODINE NO.
1a	Fresh	0.45	33.93
1b	Rancid	1.22	29.96
2a	Fresh	0.50	34.49
2b	Rancid (one month)	7.09	28.69
3a	Fresh	0.55	29.56
3b	Rancid (two months)	11.73	19.76
4a	Fresh	0.51	34.92
4b	Rancid (three months)	14.80	22.55

* Sample 1 was exposed for three months to air and light in a cold room during winter; a, represents the unoxidized bottom layer, and was unchanged; b, represents the upper oxidized part which was bleached and had an abnormal taste and smell. Samples 2b, 3b, and 4b, were allowed to become rancid in a warm place with free exposure to air and light.

Siegfeld (1909) found that melted and filtered butter when exposed to the light increased in acidity, and in the Reichert-Meissl number, and decreased in the iodine number. He says, "Oxidation is at once apparent."

Quite in contrast to the preceding statements is the report given by Crampton which agrees with the writer's work. Crampton says,

> Having in mind the very radical changes brought about in oils by the process of "blowing" or oxidation, I thought it would not be difficult to establish differences in the composition of milk fat brought about by aeration to which it is subjected in the process of renovation. The results of the few experiments I have been able to make in this direction have been negative.

A sample of creamery butter was purchased early in summer and analyzed. It was freely exposed to the atmosphere of the laboratory and even inoculated with rancid butter. It was kept in this way all summer. In three months it was badly deteriorated. It was again analyzed. The remainder was renovated. The following are the results:

TABLE 5

	FRESH	THREE MONTHS	AFTER RENOVATION
Reichert-Meissl	27.97	27.27	27.46
Acid Value		4.28	4.28

It is apparent that there was practically no change.

TABLE 6

Table showing Crampton's work at the renovating factory

	REICHERT-MEISSL NO.	ACID VALUE	IODINE NO.
First experiment			
Butter fat before blowing	28.76	7.32	37.38
Butter fat after blowing	29.73	7.28	36.50
Butter, finished product	28.58	9.95	36.67
Butter, raw stock	28.56	3.98	37.09
Second experiment			
Butter fat before blowing	29.84	5.91	38.30
Butter fat after blowing	28.88	9.11	36.76
Butter, finished product	28.77	9.01	37.28

Here again all changes were slight.

Dyer (1916) found the following results:

TABLE 7

Chemical constants of the butter fat after being nearly freed from the non-fatty ingredients by melting, filtering, and washing and stored at 0°F.

AGE	REICHERT-MEISSL NO.	IODINE NO.
Initial	30.03	37.30
Two months	30.17	37.42
Three months	29.84	36.58
Four months	29.67	36.68

TABLE 8

Chemical constants of the fat of excessively washed butter, with low content of non-fatty ingredients, stored at 0°F.

AGE	REICHERT-MEISSL NO.	IODINE NO.
Initial	30.03	37.30
Two months	29.83	36.52
Four months	29.89	36.42

TABLE 9

Chemical constants of the fat of normally washed butter, with medium content of non-fatty ingredients, stored at 0°F.

AGE	REICHERT-MEISSL NO.	IODINE NO.
Initial	30.03	37.30
Two months	30.64	36.39
Three months	30.16	36.98
Five months	29.78	36.52

TABLE 10

Chemical constants of butter fat stored at 0°F after being nearly freed from the non-fatty ingredients by melting, filtering, and washing

AGE	REICHERT-MEISSL NO.	IODINE NO.
Initial	26.16	41.91
Two months	26.90	41.40
Three months	26.71	40.76
Five months	26.93	40.79
Six months	26.84	40.88

TABLE 11

Chemical constants of the fat of unwashed butter, with high content of non-fatty ingredients, stored at 0°F.

AGE	REICHERT-MEISSL NO.	IODINE NO.
One month	26.28	41.80
Two months	26.76	40.40
Three months	26.90	40.81
Five months	26.83	40.13
Six months	26.84	40.30

It should be noted that in these tables by Dyer that both the Reichert-Meissl number and the Iodine number remain practically constant during storage.

Similar to the work by Crampton and Dyer reported above, is the following report by the author. In the winter and spring of 1909, six samples of fresh milk fat were analyzed. One division of the samples was placed at 70°F., the other was held at 90°F. All of the samples faded. Most of them became snow white throughout, even though the containers were very nearly full. The samples were held in 60 cc. beakers and left open in the light of the incubators. Not a single sample developed rancidity. All became tallowy.

TABLE 12

The effect of air, temperature and diffused light on the iodine number in butter fat

SAMPLE	FRESH	70°F.				90°F.		
		Age	Surface	Middle	Bottom	Age	Surface	Bottom
		days				*days*		
I	30.68	38	Ave. of entire sam.		32.80	294	31.32	31.66
II	32.04	336	29.27		31.11			
II	32.04	414	26.30					
III	35.45	270	29.74	30.96	30.88	330	31.73	31.78
IV	33.30	258	32.74	32.66	33.46			
IV	33.30	404	29.09					
V	33.52	251	32.46		32.92	300	28.62	30.80
V	33.52	378	26.14					
VI	33.09	242	32.26	33.14	32.08	293	28.45	30.13

It will be noticed that there was an increase in sample I, in all three determinations of the old butter-fat. In sample IV there

was an increase in the bottom determination. There was also an increase in sample VI in the middle determination at 70°F. The most marked decrease was in sample V, in the surface determination. This decrease was 7.38. Of the twenty-five determinations the average decrease was 2.40. This includes the five determinations showing an increase. The average decrease of the surface was 3.4 and of the bottom layers 1.32.

The author analyzed one sample of old butter which had been held for twelve years in a glass fruit jar, at room temperature. It had been opened frequently. The fats seemed to have risen and the casein to have settled. The flavor was very strong but not rancid.

TABLE 13

*Butter twelve years old**

IODINE NO.	REICHERT-MEISSL NO.	ACID NO.
31.54	32.80	26.1

* The author is grateful to Prof. H. C. Troy, of Cornell University, for this sample of old butter.

The acid number was the only constant that varied from the range of fresh butter.

Another old sample of butter which likewise had changed very little, had been stored in a sealed tin can. When opened it was somewhat rancid. This rancid odor disappeared in a few hours, and then the flavor was very tallowy. The color had almost entirely disappeared.

TABLE 14

Butter 680 days old

IODINE NO.	REICHERT-MEISSL NO.	ACID NO.
33.87	34.95	5.42

Eighty-seven days later the surface of the butter fat of the above sample, which had been held in an open bottle, had an iodine number of 32.05, showing a decrease of only 1.82. Rancidity did not develop.

SUMMARY

1. The chemical changes were very slight when biological agencies were held in check. These changes did not cause rancidity.

2. The enzymic development caused very little variation in the iodine number, and it produced no rancidity.

3. The exposure of butter and butter fat to high temperatures, light and air, did not cause a marked change in the iodine number, and this exposure did not cause rancidity.

4. Rancidity of butter as defined by butter dealers and expert butter judges is rarely found. The average person thinks of the strong flavor of butter as rancid.

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THE COMPOSITION AND MARKET QUALITIES OF BUTTER WHEN CORN SILAGE IS FED WITH COTTONSEED MEAL[1]

L. S. PALMER AND D. P. CROCKETT

Department of Dairy Husbandry, University of Missouri

One of the most important facts brought out in a recent bulletin (1) regarding the effects which the feeding of cottonseed products exerts upon the composition and properties of butter was the tendency for certain roughages to counteract in large measure the usual results which follow the use of cottonseed meal. Attention was directed particularly to the counteracting influence of corn silage. The greater part of the data, however, were in regard to the physical and chemical constants of the butter fat. These data showed that the depressed saponification value and Reichert-Meissl number, and augmented iodin value and melting point of butter fat which characterize the feeding of liberal amounts of cottonseed meal are returned to their normal figures when the roughage is changed to one of corn silage, and the usual changes, with the exception of a partial one in the melting point of the fat, do not occur when cottonseed meal is added to a ration in which corn silage constitutes the major part of the roughage.

The feeding of cottonseed meal with dry roughage also causes characteristic changes in the market qualities of butter. The effect of the meal first becomes evident in the changed body of the butter. It is uniformly harder and more resistant, and is usually brittle and crumbly when cold. The butter is also characterized by an oily flavor, and there is a general absence of the quick, fresh taste of normal butter, although there is more often a general lack of flavor than any taint or bad flavor. The butter is much more resistant to pressure than is normal, and the high melting point of the butter fat causes the butter to

[1] The essential facts in this paper are taken from the dissertation presented by Dura P. Crockett for the degree of Master of Arts, University of Missouri, 1917.

melt slowly in the mouth. Eckles and Palmer, in the bulletin referred to, show that some of these characteristics, particularly the oily state and hard body, attain very objectionable proportions when the ration contains relatively large amounts of whole cottonseed which is especially rich in oil.

Certain additional characteristics of butter from cottonseed meal feeding are described by these investigators. A better

TABLE 1.

Plan of experiment and average ration consumed in each period

PERIOD	DATE	GROUP I		GROUP II	
			lbs.		lbs.
1	November 5 to November 23, 1916	Silage	29	Silage	28
		Hay*	9	Hay	9
		Grain†	8	Grain	9
2	November 23 to December 15	Silage	29	Hay	18
		Hay	9	Grain	7
		Grain	6	Cottonseed meal	3
		Cottonseed meal	3		
3	December 15 to January 1, 1917	Silage	29	Hay	18
		Hay	9	Grain	4
		Grain	4	Cottonseed meal	5
		Cottonseed meal	5		
4	January 1 to January 21	Silage	29	Silage	28
		Hay	9	Hay	10
		Grain	7	Grain	9

* The hay fed to both groups throughout the entire experiment was a mixture of equal parts alfalfa and timothy.

† The grain fed to both groups throughout the entire experiment was a mixture of corn meal two parts, distillers grains one part, wheat bran one part.

standing-up quality or resistance to heat and a marked improvement in keeping quality were found to accompany the feeding of cottonseed meal.

A somewhat limited amount of data were presented by Eckles and Palmer, however, with regard to the extent to which corn silage counteracts the peculiar market qualities of cottonseed

meal butter, just described. Inasmuch as this phase of the question is of considerable practical importance it seemed worthy of more extended study. It is the purpose of this paper to present the results of an experiment which was carried out with that end in view.

PLAN OF STUDY

Twelve pure-bred cows were selected from the University herd and divided into two groups of six cows each. At the beginning of the third period of the experiment it became necessary to drop one cow from group I on account of the rapid decrease in her milk flow. The experiment was completed with only five animals in this group. The entire study was divided into four periods. The first and last periods were basal, in which both groups received a ration of corn silage, hay and grain. In the intervening periods a portion of this grain was replaced by 3 and 5 pounds of cottonseed meal, respectively, and in addition the roughage of group II was changed to hay only. The general plan of the experiment, together with the average ration consumed by each group in each period, and the duration of each period, is shown in table 1.

All the milk produced by the two groups during the last three days of each period was separated and the cream ripened with a commercial starter. The conditions were controlled as closely as possible throughout the process of separating, holding, and churning the samples. To provide against loss or accident, the cream from each group was handled in duplicate, the first three milkings constituting the "A" churning, and the last three milkings the "B" churning. The cream was churned in a semi-commercial way, and as soon as the butter was salted and worked, samples were prepared, (1) for scoring and analysis, (2) for a study of the keeping quality, (3) for the determination of the physical and chemical constants of the fat.

One-pound prints of the butter were made for scoring. A portion of this butter was prepared for analysis for moisture, fat, curd, ash and salt according to the official method of the

American Association of Official Agricultural Chemists.[3] The indirect method for fat was used.

For a study of the keeping quality, six 2½ ounce metal-capped glass jars were packed with the butter from each churning. The jars containing the "B" churnings were immersed in strong brine and kept in the refrigerator, at a temperature of 8 to 12°C. One jar could thus be examined at any time without disturbing the other samples. The jars containing the "A" churnings were kept at room temperature. After the samples had been kept for a few weeks the tops were dipped in paraffin to prevent the entrance of molds, which were beginning to contaminate some of the samples. This treatment effectively prevented any further mold contamination.

For the examination of the fat constants a half pound sample for each churning was rendered, and the filtered fat subjected to analysis for saponification value, Reichert-Meissl number, iodin value (by the Hübl method) and melting point. The Leffman-Beam method was used for the Reichert-Meissl number and Wiley's method for the melting point. The results from the two churnings were averaged in each case.

RESULTS OF EXPERIMENT

Composition of butter. The analyses of the different churnings of butter for moisture, fat, curd, ash and salt are given in table 2. An examination of the figures shows no differences in the composition of the different samples of butter which can be attributed to the changes in the ration.

Score of butter. The market quality of the various samples of butter as shown by the usual method of scoring is given in table 3, together with the characteristics of the ration which have a bearing upon the results. These scores were made by Prof. M. Mortensen of the Iowa State College, who judged the samples without any knowledge of the conditions under which they were made. For this purpose samples from each churning, except those in the first basal period, were packed in paraffined cartons and shipped at once to Professor Mortensen.

[3] United States Department of Agriculture Bulletin 107, Bureau of Chemistry. Revised edition, 1908.

TABLE 2

Composition of butter in each period

PERIOD	GROUP	CHURNING	WATER	FAT	CURD	ASH	SALT
			per cent	*per cent*	*per cent*	*per cent*	*per cent*
1	I	A	11.80				
		B	10.60				
	II	A	12.00				
		B	13.00				
2	I	A	15.68	81.50	1.12	1.73	1.72
		B	15.57	80.80	1.19	2.61	2.75
	II	A	14.90	80.50	2.08	2.77	2.75
		B	15.90	79.80	1.14	3.36	3.42
3	I	A	14.97	81.70	1.19	2.16	2.17
		B	15.52	80.95	1.06	2.54	2.05
	II	A	15.22	81.35	0.99	2.46	2.59
		B	16.62	80.15	1.07	2.21	2.26
4	I	A	15.79	81.35	0.96	2.05	2.03
		B	17.40	77.90	1.63	3.31	3.24
	II	A	15.47	79.90	1.31	3.48	3.34
		B	14.70	82.50	0.93	2.31	2.26

TABLE 3

Score of experimental samples of butter

PERIOD	GROUP	CHURNING	RATION		SCORE OF BUTTER		
			Cottonseed meal	Silage	Flavor	Body	Total
			pounds per day	*pounds per day*	*per cent*	*per cent*	*per cent*
2	I	A	3	29	36.0	25	91.0
		B	3	29	37.0	25	92.0
	II	A	3	00	37.0	25	92.0
		B	3	00	37.5	25	92.5
3	I	A	5	29	36.0	25	91.0
		B	5	29	36.5	25	91.5
	II	A	5	00	37.0	25	92.0
		B	5	00	37.0	25	92.0
4	I	A	0	29	36.0	25	91.0
		B	0	29	35.5	25	90.5
	II	A	0	28	35.5	25	90.5
		B	0	28	36.0	25	91.0

On examining the data in table 3 it is seen that all the samples of butter were of good quality, the only defect from a commercial point of view being in flavor. Certain slight defects in body were noted in some cases, however, but these were not sufficiently pronounced to lead to a deduction in the score. For example, the butter from three of the churnings of period 2 was characterized as hard and brittle, but this was not noticed in the case of the "B" churning of group II. Similarly, the body of both churnings of group I in period 3 was stated to be hard, although not objectionably so, while no note was made in regard to the body of either churning from group II in this period. With regard to the oily flavor which frequently characterizes cottonseed meal butter, this was noticed only in the case of the two churnings from group I in period 3, and the "A" churning from this group in period 2, and then only to a slight extent, although the latter sample was stated to have a greasy, flat taste.

All the samples of butter were also examined by the authors in conjunction with Dr. C. H. Eckles of the Department of Dairy Husbandry, University of Missouri. The butter produced in each of the basal periods was judged to be of good quality, and very uniform in this respect among the different churnings of each of the two periods. Each of the churnings of period 2 was judged by us to have a slight taste of oil. There appeared to be no difference in this respect between the samples which could be attributed to the character of the roughage. An oily flavor and higher melting point were more noticeable in period 3. All the samples possessed these characteristics to some extent, but they seemed to be more pronounced from Group I, as was also noted by Professor Mortensen. The samples from Group II in this period seemed to be characterized more by a lack of flavor rather than by any pronounced off flavor. In no case, however, were these characteristics as pronounced as is frequently obtained in cottonseed meal feeding.

The results of the present experiment on the market qualities of the butter may be summarized as follows:

1. Cottonseed meal, when fed in quantities of 3 to 5 pounds,

imparted a slight oily flavor and harder body to the butter, but these defects were not sufficiently pronounced to detract materially from the market value of the butter.

2. The effects of the cottonseed meal feeding were fully as pronounced when fed with corn silage, as when a mixture of alfalfa and timothy hay constituted the only roughage.

Keeping quality of butter. Previous experiments carried out by this department (1) have been uniform in showing that butter made when cottonseed meal forms a part of the ration retains its original flavor appreciably longer than when no cottonseed meal is fed. Observations were accordingly made in this experiment in regard to the keeping quality of the various samples of butter. Although all the "A" churnings were kept at room temperature, and the "B" churnings at 8 to 12°C., the observations made upon the latter samples only will be reported as they imitated ordinary storage conditions more closely.

At the end of two months storage the basal samples lacked the quick flavor of fresh butter. At the end of three months a strong, old taste was sufficiently pronounced to make the butter unacceptable for table purposes. On the other hand the butter made on the cottonseed meal rations was judged to be in as good condition after two months as when put in storage, and at the end of three months was superior to that from the basal periods, being of about the same quality at this time as the basal butter at the end of two months. At the end of four months the samples from group I, which represented the feeding of cottonseed meal and silage had not deteriorated as much as the samples representing the feeding of cottonseed meal and hay.

The general result of the study, then, was to confirm the former results showing a superior keeping quality of butter made on a cottonseed meal ration over that made when the ration contains no cottonseed meal.

Chemical and physical constants of butter fat. The results of the analyses of the butter fat are shown in table 4.

The degree of heat which butter will withstand before losing its shape is of some economic importance in connection with serving the butter for table use. The highest temperature to

which butter can be heated without entirely spreading out has been designated in past studies of the kind in this department as the "standing-up temperature" of the butter. Since this point is closely related to the melting point of the butter fat the standing-up temperatures of the various samples of butter secured in this experiment have been included with the chemical and physical constants of the butter fat, and are also shown in table 4. The general method of making this determination has already been described (1) and need not be repeated. A slight improvement over the original method may, however, be mentioned.

TABLE 4

Chemical and physical constants of butter fat on different rations

PERIOD	GROUP	SAPONIFICATION VALUE	REICHERT-MEISSL NUMBER	IODIN VALUE HÜBL.	MELTING POINT	STANDING-UP TEMPERATURE
					°C.	°C.
1	I	234.9	31.66	28.10	32.90	34
2	I	232.9	30.95	29.01	34.18	34–35
3	I	233.4	31.03	28.88	34.10	35–36
4	I	232.2	29.63	30.22	33.03	34
1	II	236.8	33.27	29.70	32.38	33
2	II	229.2	29.63	34.69	34.35	34–35
3	II	227.4	30.01	34.42	33.98	35–36
4	II	232.5	30.73	32.11	32.45	33

The determinations reported in this paper were carried out in an electrically heated oven, in which a uniform distribution of heat was maintained by the use of a small electric fan, the blade of which was suspended through the top of the oven by means of an extended shaft.

The constants of the butter fat of group I in all periods, and of group II in periods 1 and 4 were characteristic of silage feeding as has been pointed out in a previous publication (1). Abnormally high saponification and Reichert-Meissl values and an abnormally low iodin value are the striking features of the fat constants during liberal silage feeding. The replacement of part of the grain by 3 and 5 pounds of cottonseed meal in periods 2 and 3, respectively, in the case of Group I, was without effect

upon these fat constants when the data are compared with both basal periods. This result was in entire agreement with the result secured in a similar experiment previously conducted, the data from which have already been published.[1] The melting point of the fat was increased slightly, however, by the cottonseed meal in periods 2 and 3, and this effect was also noticed in the increased standing-up temperature of the butter. This result was also in harmony with that obtained in the experiment to which reference has been made, in which the only effects of the addition of as high as 6 pounds of cottonseed meal to a ration in which silage comprised a liberal portion of the roughage was a small increase in the melting point of the fat and a similar rise in the standing-up temperature of the butter.

Very different results characterized the feeding of the cottonseed meal in periods 2 and 3 in the case of group II, in which the roughage was also changed to one of hay only. A marked depression of the saponification and Reichert-Meissl values and increase in the iodin value and melting point characterized the fat constants in these periods in comparison with the constants of the fat in the basal periods. The standing-up temperature of the butter was also increased. Such effects are characteristic of cottonseed meal feeding when dry roughage is fed. This experiment does not show, however, the extent to which the changes in the fat constants of periods 2 and 3 are due to the feeding of cottonseed meal because these periods were also characterized by a removal of silage from the ration. The results were no doubt due in part to this change in roughage.

One or two other features of the data in table 4 may be mentioned. It is noticed that the fat constants of group II were not abnormal in any of the periods, even in period 3 when 5 pounds of cottonseed meal were fed with a dry roughage of hay only. In this respect the results differ somewhat from those already published from this laboratory. They are probably due, in part at least, to the fact that the fat constants were already abnormal in the opposite direction from those which usually characterize cottonseed meal feeding when the ration was changed to include the cottonseed meal. From this point of

view the changes in the fat constants which accompanied the introduction of the meal into the ration were as great as would be expected from the amount of cottonseed meal fed.

Another feature of the data in agreement with previous experiments conducted with cottonseed meal feeding was that no greater effects were secured when 5 pounds of meal were fed to group II than when 3 pounds were fed. Previous work carried out on this question in this laboratory has shown conclusively that the effects of cottonseed products upon the constitution of butter fat are due to the oil which they contain; at the same time it was shown that less effects may frequently be expected when the oil is fed in connection with cottonseed meal, especially when moderate quantities of meal are fed, than when the oil is fed directly. It is admitted that this may not be the entire explanation of this result. No doubt the true explanation involves much more fundamental questions than are capable of explanation with the present state of knowledge of the factors governing the synthesis of milk fat.

Very great difficulty is also experienced in attempting to explain why the addition of cottonseed meal to a ration containing a liberal portion of silage fails to affect any of the fat constants except the melting point of the butter fat. Both the withdrawal of silage from the ration and the addition of cottonseed meal to a ration containing dry roughage cause changes in the fat constants in the same direction. One would expect, therefore, that the addition of cottonseed meal to a silage ration would exert whatever change is characteristic of cottonseed meal alone, although the final result might not be an abnormal butter because of the direction of the change in the fat constants which silage alone causes. Repeated experience has shown, however, that the effect of the silage feeding is apparently much stronger, at least upon the chemical constants of the milk fat, than the effect of cottonseed meal feeding. Although admittedly very inadequate, this is the only explanation the authors can suggest for the result which accompanies the addition of cottonseed meal to a ration already containing a liberal amount of corn silage.

SUMMARY

The results of the experiment reported in this paper may be summarized as follows:

1. The feeding of 3 to 5 pounds of cottonseed meal with a liberal ration of corn silage caused just as pronounced an oily flavor and as much increased hardness in the butter as when the same quantities of cottonseed meal were fed with hay alone. In neither case, however, were the market qualities of the butter impaired sufficiently to detract from its market value.

2. The use of corn silage as roughage tended to counteract the increased heat resistance of butter which accompanies the feeding of cottonseed meal.

3. The feeding of cottonseed meal materially retarded the rate of deterioration of butter kept at 8 to 12°C. This effect was secured when the cottonseed meal was fed with corn silage as well as when it was fed with hay.

4. The liberal use of corn silage in a ration counteracted all the effects which 5 pounds of cottonseed meal usually exerts upon the chemical constants of butter fat in that the addition of the cottonseed meal to a ration containing a liberal amount of corn silage was without effect upon the fat constants. A slight increase in melting point, however, accompanied the feeding of the cottonseed meal.

REFERENCE

(1) Eckles, C. H. and Palmer, L. S.: Effects of feeding cottonseed products on the composition and properties of butter. Missouri Agr. Exp. Station Research Bulletin 27, pp. 44, figures 3, 1916.

THE DAILY PER CAPITA CONSUMPTION OF MILK

H. F. JUDKINS

Department of Dairy Husbandry, Connecticut Agricultural College

While it is difficult to compile any accurate figures on the daily per capita consumption of milk it is generally conceded that the average for the United States is about 0.6 of a pint. This is a little more than a glass a day. That this is too small an amount is beyond question.

Adults in particular should remember the days of their youth and use more milk than they do. Were it not for the infant the per capita consumption would be much less than it is. According to Vermont Bulletin 195, one-sixth of the milk produced by our 22,000,000 cows is used as a food for infants and young children. It has been figured that the infant consumes 530 quarts of milk during the first year of its life.

In order to study the per capita consumption of milk first hand and find out the effect of the infant on the amount of milk used in various families data were tabulated on 27 families living in Storrs. The College retails about 90 quarts daily to residents of Storrs and hence accurate records were available. The time covered was about three months when college was in session. Families in which the exact numbers were known as well as the approximate age of children were selected. These families were divided into three groups.

It will be noted in group I that the "youngsters" were the cause of nearly doubling the consumption over group II and that it is a half pint more than in group III. It can be seen that while there is some variation in the amount used by the different families in the different groups the amount is fairly constant.

In group III it can be seen that a quart of milk is about the standard amount for a family of two. There is no better food for growing boys and girls until they reach maturity than milk. It is plainly seen that it is not realized, or at least practised by families in group II, having children three to twelve years of

age when the consumption is much less than group I. The probable reason why the consumption is a little greater in group III than in group II is that a pint of milk was not enough to accommodate the family of two and so a quart had to be purchased and the milk used a little more freely.

The daily consumption for Storrs of 1.07 pints per capita is considerably larger than for the country. This is probably explained by the fact that the people have all had some education as to the importance of milk as a food and that they know the

Group I

Families with one or more children under three years

NUMBER OF FAMILY	NUMBER OF DAYS	NUMBER OF PINTS	AVERAGE DAILY CONSUMPTION	NUMBER IN FAMILY	AVERAGE PER CAPITA (PINTS)
1	101	418	4.13	4	1.03
2	101	472	4.67	3	1.56
3	103	793	7.69	5	1.54
4	80	468	5.85	4	1.46
5	113	633	5.60	4	1.40
6	108	782	7.15	4	1.79
7	104	574	5.48	5	1.09
8	102	454	4.45	3	1.48
9	107	624	5.83	4	1.46
10	100	461	4.61	3	1.54
Total.....	1019	5679	55.46	39	
Average.....	101.9	567.9	5.546	3.9	1.42

Group II

Families with children three to twelve years

NUMBER OF FAMILY	NUMBER OF DAYS	NUMBER OF PINTS	AVERAGE DAILY CONSUMPTION	NUMBER IN FAMILY	AVERAGE PER CAPITA (PINTS)
11	109	416	3.81	6	0.63
12	93	208	2.13	3	0.71
13	93	416	4.47	5	0.89
14	98	211	2.15	3	0.72
15	98	312	3.18	4	0.79
16	95	217	2.28	3	0.76
Total.....	586	1780	18.02	24	
Average.....	97.6	296.6	3.003	4	0.75

Group III

Families with no children

NUMBER OF FAMILY	NUMBER OF DAYS	NUMBER OF PINTS	AVERAGE DAILY CONSUMPTION	NUMBER IN FAMILY	AVERAGE PER CAPITA (PINTS)
17	79	156	1.96	2	0.98
18	89	156	1.75	2	0.78
19	94	208	2.21	2	1.10
20	24	53	2.03	2	1.10
21	64	106	1.65	2	0.83
22	82	157	1.97	2	0.96
23	75	104	1.39	2	0.69
24	93	160	1.72	2	0.86
25	74	156	2.10	3	0.70
26	92	209	2.27	2	1.14
27	71	52	0.73	2	0.37
Total.....	873	1517	19.72	23	
Average.....	76.09	135.1	1.79	2.0	0.895

Summary table

GROUPS	AVERAGE NUMBER IN FAMILY	AVERAGE DAILY CONSUMPTION (PINTS)	AVERAGE PER CAPITA CONSUMPTION (PINTS)
I	3.9	5.54	1.42
II	4.0	3.00	0.75
III	2.0	1.79	0.895
Average per 27 families.....	3.22	3.45	1.07

supply is of the best. Children under five years of age are also plentiful in Storrs.

The population of Connecticut in 1910 is given as 1,114,756. By this time it is probably at least 1,300,000. If this is the case and the average per capita consumption for this mass of people was the same as for Storrs, 1.07 pints, rather than 0.6 of a pint a day it would mean a demand for 799,000 more pounds of milk daily or 291,635,000 pounds yearly. While the recent survey on the cost of milk production showed that the average production for 3238 cows was 6009 pounds yearly it is probable that the production for the state is about 5500 pounds. This

being the case, it would take 53,024 more cows to take care of the increase in consumption of milk.

The writer was curious to get some idea as to what was the per capita consumption of milk on the farms where it was produced. A questionnaire was sent out to 25 farms, most of them retailing milk, and 17 replies were received. The data is presented below.

Table showing daily per capita consumption in pints on seventeen Connecticut dairy farms

NUMBER OF FAMILY	NUMBER IN FAMILY	NUMBER OF PINTS	DAILY PER CAPITA (PINTS)
1	6	8.0	1.33
2	6	6.0	1.00
3	2	4.0	2.00
4	4	7.0	1.75
5	6	8.0	1.33
6	4	4.0	1.00
7	3	6.0	2.00
8	5	3.0	0.60
9	5	7.0	1.40
10	3	6.0	2.00
11	6	7.0	1.16
12	8	16.0	2.00
13	10	10.4	1.04
14	7	12.0	1.71
15	6	8.0	1.33
16	13	8.0	0.61
17	6	10.0	1.66
17	100	130.4	1.30

It will be noted that there is considerable variation in different families. The average of all of them is 1.3 pints. While this is slightly larger than for those purchasing their milk it would seem that there was a chance for the farmer to use more of his own product to good advantage.

All the figures presented were obtained under winter conditions. It is probable that in the summer time the consumption is higher, both in the town and on the farm. Hot weather is the "bread and milk season" and on the farm in particular, the big pitcher of milk for drinking purposes has a prominent place.

A STUDY OF SOME FACTORS CONCERNED IN THE PREPARATION OF MILK FERMENTED WITH B. BULGARICUS AND BACT. LACTIS ACIDI

R. FINKELSTEIN

Department of Bacteriology, Ontario Agricultural College, Guelph, Canada

INTRODUCTION

A desire for better utilization of creamery by-products has led to the present study.[1] Natural buttermilk, as is well known, in too many cases finds its way into the drains. In some instances it is used as hog or poultry feed. In other cases, however, it is put out on the market in cities and towns to a limited extent, but has not generally gained in favor partly because of its lack of uniformity and partly because of its poor keeping quality, that is, tendency to whey off and to go off flavor.

In the disposal of skim milk, too, there is quite a noticeable waste. While much of it is fed to the growing young stock and while much of it is used in manufacturing fancy cheese, skim milk cheese, casein and milk sugar, there is at the same time a decidedly large amount of it going to waste.

A better use for buttermilk and skim milk could, perhaps, be found in the human consumption. If placed on the market in the form of properly fermented products of uniform quality and reasonably good keeping quality, they could probably fill a growing, but as yet an unstimulated, demand.

PURPOSE OF THIS STUDY

The effect of B. bulgaricus on ripened skim milk and on ripened whole milk has been studied at different temperatures in an effort to find out the best practical method of preparing milk drinks with these lactic acid types of organisms, as well as to determine the behaviour of different mixtures under varying treatments.

[1] The investigation had been carried out at Cornell University in 1915.

Buttermilk obtained from raw cream has a varied bacterial flora as it comes from the churn. If derived from pasteurized ripened cream, the buttermilk contains chiefly bacteria of the lactic acid type. Its body is thin and watery and it has a great tendency to whey off. To counteract this as well as to improve the flavor and the body, experiments have been performed with B. bulgaricus added in different proportions to buttermilk.

METHODS USED

The milk was heated in Erlenmeyer flasks in the steam bath for fifteen minutes, then rapidly cooled to 100° F. and poured into sterile 125 cc. dilution bottles till they were about three-fourths full. These were then inoculated with B. bulgaricus grown in sterile litmus skim milk tubes which were propagated from day to day. When ripe they were mixed, in different proportions, with freshly ripened Bact. lactis acidi milk, or fresh buttermilk, care being taken to run "check" bottles both on B. bulgaricus, Bact. lactis acidi and buttermilk in order to have a basis for comparison.

The mixtures and checks were prepared in three sets and each set held at a different temperature. The bottles were then examined from time to time and the effect of different temperatures on different mixtures was observed.

The results obtained in this work are indicated in the summary tables 1, 2 and 3 that follow.

In table 4 a comparison is drawn between B. bulgaricus cultures in skim-milk and in whole milk having different degrees of final acidity, which shows the effect of this factor on the flavor and the body of the resulting product.

RESULTS OF PRELIMINARY WORK ON PROPAGATING B. BULGARICUS IN MILK

1. Inoculations ranging between 0.25 and 4 per cent showed no differences in their effect on body, flavor or time required for ripening. Each one ripened pasteurized skim-milk inside of twenty-four hours at 100° F.

2. Ripening at 100° F. for two to four days does not result in the appearance of whey, but the high acid that is thus developed is obtained at the loss of body.

TABLE 1

Study of temperatures vs. keeping quality of lactic cultures and buttermilk; also study of amount of B. bulgaricus culture required to improve their body, flavor and keeping quality

TEMPERATURE	CULTURES IN PASTEURIZED SKIM-MILK
Ice-box 30–56°F.	(1) B. bulgaricus culture.*—Shows excellent keeping quality. Ropiness and body but slightly lost in two to three weeks. (2) Bact. lactis acidi culture.†—Shows no whey inside of two to three weeks. (3) Bact. lactis acidi culture + 25 per cent B. bulgaricus‡.—Body keeps better than in B. bulgaricus culture only. Improved flavor as compared to Bact. lactis acidi culture only.
Room 56–76°F.	(1) B. bulgaricus culture.—Loses ropiness and body in five or six days. (2) Bact. lactis acidi culture.—No whey in four days. (3) Bact. lactis acidi culture + 25 per cent B. bulgaricus culture.—Body improved for four to seven days then slowly lost, but keeps better than in B.B. alone. Flavor of mixture is improved.
Incubator 100°F.	(1) B. bulgaricus culture.—Wheys off in two days; loses body in three days. Gains rapidly in acid and flavor. (2) Bact. lactis acidi culture.—Wheys off rapidly, almost immediately. (3) Bact. lactis acidi culture + 25 per cent B. bulgaricus culture.—Wheying off delayed for three days. B.B. makes vigorous growth till the product becomes undistinguishable from B.B. check.

* Will be referred to later as B.B. culture.

† Will be referred to later as B. la. culture.

‡ Additions of B. bulgaricus culture ranging from 10 to 100 per cent have been tried out. Additions of less than 25 per cent were too small to bring about good results, while additions of more than 25 per cent made the product too acid and too thick to be palatable. Hence the addition of 25 per cent has been adhered to in these experiments.

3. Loss of body of B. bulgaricus-ripened skim-milk may be due to any one of these factors or to a combination of them—(a) high acid development, (b) temperature, (c) age.

SOURCE OF B. BULGARICUS

Cultures of B. bulgaricus for use in preparation of fermented milk can be found on the market in various forms. Usually, though, the liquid cultures are preferred to the powder cultures

TABLE 2

Study of temperatures vs. keeping quality of lactic cultures and buttermilk; also study of amount of B. bulgaricus culture required to improve their body, flavor and keeping quality

TEMPERATURE	CULTURES IN PASTEURIZED WHOLE MILK
Ice-box 30–56°F.	(1) B. bulgaricus culture.—Shows no whey or loss of body in twelve days; losses ropiness but slightly. (2) Bact. lactis acidi culture.—Shows no whey or loss of body in twelve days. (3) Bact. lactis acidi culture + 25 per cent B. bulgaricus culture.—Shows no whey or loss of body in 12 days. Body and flavor (mild, rich, pleasant) improved.
Room 56–76°F.	(1) B. bulgaricus culture.—No whey in 2 weeks; loses body in five to six days. (2) Bact. lactis acidi culture.—No whey and no loss of body in two weeks. Retains its body better than B.B. check or mixtures. Very rich flavor in whole milk. (3) Bact. lactis acidi culture + 25 per cent B. bulgaricus culture.—No whey and no loss of body in two weeks. 25 per cent addition of B.B. shows up the best flavor, as compared to 10, 50 and 100 per cent additions.
Incubator 100°F.	(1) B. bulgaricus culture.—No whey in twelve days, but body lost in two days. Does not keep its body as well as the mixtures. (2) Bact. lactis acidi culture.—Wheys off in less than a day. Body not lost. (3) Bact. lactis acidi culture + 25 per cent B. bulgaricus culture.—Slight wheying off at first due to B. la. and high temperature, but B.B. develops rapidly and prevents it. Body not lost. No whey in twelve days at least. 10, 21, 50 and 100 per cent mixtures become nearly identical after several days,—show no whey, but develop high acid and strong flavor.

on account of their greater vigor. To determine the bacteriological purity of the cultures obtained, inoculate them into sterile bouillon tubes and incubate these for at least five days at

100° F. If growth takes place, it indicates contamination of the commercial culture, and if there is no evidence of growth it indicates that the culture is not contaminated. To test the activity or vigor of the same, inoculate several sterile litmus skim-milk tubes and incubate them for about twenty-four hours

TABLE 3

Study of temperatures vs. keeping quality of lactic cultures and buttermilk; also study of amount of B. bulgaricus culture required to improve their body, flavor and keeping quality

TEMPERATURE	BUTTERMILK FROM PASTEURIZED AND RIPENED CREAM
Ice-box 30–56°F.	(1) Buttermilk—good flavor; becomes old and flat in five days. Thin body at the start; shows 20 per cent whey in five days. (2) Buttermilk + 10 per cent B. bulgaricus culture.—Body slightly thickened even after five days; shows 10 per cent whey. (3) Buttermilk + 20 per cent B. bulgaricus culture.—Body slightly thickened even after five days; shows 5 per cent whey. Improved flavor—nice and pleasant.
Room 56–76°F.	(1) Buttermilk.—Thin watery body; curd separates on standing. 60 per cent whey in one day. Flavor becomes flat in three days. (2) Buttermilk + 25 per cent B. bulgaricus culture.—Body slightly thickened; 20 per cent whey in one day; 30 per cent in three days. Improved flavor; wheying tendency reduced. (3) Buttermilk + 50 per cent B. bulgaricus culture.—Improved body; 20 per cent whey in one day; 25 per cent in three days. Moderately sharp flavor appears; wheying tendency reduced.
Incubator 100°F.	(1) Buttermilk.—Thin body; 75 per cent whey in one day. (2) Buttermilk + 25 per cent B. bulgaricus culture.—Body improved in three days. 30 per cent whey in one day. (3) Buttermilk + 50 per cent B. bulgaricus culture.—Body improved in one day. 30 per cent whey in one day. In three days the buttermilk flavor is lost and the B. bulgaricus flavor replaces it completely.

at 100° F. At the end of this time, or soon after, the milk should be solidly coagulated, should show no whey and no gas, but should have a smooth, heavy body (ropy, perhaps) and a clean, sharp acid flavor.

It is possible to isolate B. bulgaricus from milk. Examine microscopically several different samples of milk for the possible

TABLE 4

Relations between amount of acid, flavor, body and time as factors in B. bulgaricus cultures

PASTEURIZED SKIM-MILK					PASTEURIZED WHOLE MILK				
Amount of acid calculated as lactic	Flavor.	Body	Held		Amount of acid calculated as lactic	Flavor.	Body	Held	
			Days	Temperature				Days	Temperature
per cent					*per cent*				
0.42	None	None	1	60–66°F.	0.70		Slightly thick	1	60–66°F.
0.62	None	Slightly thick	1	60–66°F.					
0.82	Slightly sour	Slightly thick	1	60–66°F.	0.95	Suggestion of a flavor	Moderately thick	1	60–66°F.
1.6	Moderately sharp	Thick	1	37°C.	1.63	Mild. Pleasant	Thick	1	37°C.
1.7	Moderately sharp	Very thick.	1	37°C.					
1.75	Moderately sharp	Fairly thick; slightly wheyed off	1	37°C.					
2.15	Very sharp	Thick	2	37°C.	2.15	Moderately sharp	Thick	2	37°C.
2.23	Very sharp	Moderately thick	Ripened at 37° C. then						
			42	32°F.					
2.15	Very sharp	Thin	9	32°F.	2.15	Moderately sharp	Thick	2	37°C.
2.53	Very sharp	Very thin; wheyed off	9	32°F.	2.25	Sharp	Very heavy	1	37°C.
2.57	Very sharp	Slightly thick; slightly wheyed	7	32°F.	2.45	Very sharp	Very thin; slightly wheyed off		

NOTE: The best body and flavor in skim-milk ripened with B. bulgaricus are found when there is about 1.7 per cent acid. Practically the same conclusion was reached by LeRoy Lang (Illinois circular 166, May, 1913).

Under similar conditions for whole milk, the best body and flavor are found when there is about 2.0 per cent acid.

presence of B. bulgaricus and heat, in cotton-plugged test tubes for ten minutes at 140° F., the ones giving a probable positive test. Then cool them to 100° F. and allow to sour at this temperature. This being a favorable temperature for its growth, and other organisms mostly killed off, B. bulgaricus that is likely to be present in milk develops in a characteristic way. Propagate the more vigorous cultures for several days by making daily transfers to sterile litmus skim-milk tubes and thus purify them. Where several tubes are available for propagation it is well to select the ones possessing the most desirable properties: vigor, flavor and body. Keep in the refrigerator as "stock" cultures for two or three weeks tubes purified and selected in this way, then propagate them and again treat some of them as "stock" cultures.

REMARKS ON PREPARATION OF MILK FERMENTED WITH B. BULGARICUS AND BACT. LACTIS ACIDI

B. bulgaricus grown in milk gives a flavor moderately sharp to sharp, which is not altogether tolerable to some people. It also produces a thick, ropy body which is unsightly and in which condition it cannot be used as a beverage without an effort.

To strike a happy medium (that is, to use B. bulgaricus for nutritive and therapeutic purposes and to utilize to good advantage the creamery by-products) it becomes necessary to mix cultures of B. bulgaricus and Bact. lactis acidi in a proportion that would have no ropiness, that would have a slightly thick body, a distinctive pleasant taste and good keeping qualities. Such a proportion has been found in these experiments to be one part of freshly prepared B. bulgaricus culture and four parts buttermilk or of Bact. lactis acidi grown either in skim-milk or whole milk and kept at a temperature below 56° F.

As indicated elsewhere in this paper, obtain a pure culture of B. bulgaricus which is vigorous and which has a moderately sharp B. bulgaricus flavor, a thick, ropy body and no whey. Inoculate about 1–5 per cent of it into good pasteurized (150° F. for thirty minutes) milk at 100° F., mix it thoroughly and incu-

bate for twenty to twenty-four hours at this temperature. If not ready to mix at the end of that time, put away this freshly ripened milk at 56° F. or lower.

Using a good culture of Bact. lactis acidi, inoculate one to five per cent of it into pasteurized milk, mix it thoroughly, and incubate at 60 to 70° F. for about twenty-four hours. At that time it should be free from gas and whey, should have a fine smooth body and a mild, clean acid flavor. The acid should test about 0.7 per cent.

If the Bact. lactis acidi culture is good it keeps in good shape for at least two to three weeks both in skimmed and in whole milk at 32 to 76° F. At about 100° F. it wheys off at once in skim-milk and in less than a day in whole milk. The value of B. bulgaricus then is in prevention of wheying off of Bact. lactis acidi cultures at temperatures above 76° F. In order to do this it is necessary to add one part of B. bulgaricus culture to four parts of Bact. lactis acidi culture and to churn for a few minutes in order to break up lumps.

If buttermilk from pasteurized ripened cream is to be used one must use some judgment as to the amount of B. bulgaricus to add 10 to 20 per cent of it is necessary to improve the body and flavor of buttermilk. If whey separates out of the buttermilk too readily, it may become necessary to add as much as 30 per cent or more of a heavy-bodied, moderately flavored B. bulgaricus culture and to keep the mixture at a low temperature, that is, below 56° F.

Outside contamination of B. bulgaricus cultures must be guarded against. A common source of trouble is that of molds which are likely to get in and spoil the product. Molds grow at low and high temperatures; they grow in acid media and once they get a foothold in the cultures they are likely to be propagated in the daily transfers, unless their presence is noted and the contaminated cultures discarded. They are usually detected by their smell and taste and by the color of their spreading green colonies or brownish spots or white slimy covering on the surface of the culture, or else by microscopic examination.

A possible explanation of the formation of the firm jelly-like

body in B. bulgaricus milk cultures and the consequent partial loss of the same can be found in the following quotations:

Dr. Hastings (1): "Members of Bact. bulgaricum group do not liquefy gelatin, but casein is partly changed into soluble decomposition products."

Dr. Clement A. Penrose (2): "Probably an enzyme is formed which coagulates milk, for the curdling takes place even when the acid is neutralized with calcium carbonate or calcium chloride or zinc chloride in excess."

CONCLUSIONS

1. B. bulgaricus cultures partly lose with age their body and ropiness at temperatures ranging from 32 to 100° F. which is due to high acidity, or to temperature, or to age, or to reduction in bacterial numbers (3), or to a combination of any of these factors.

2. B. lactis acidi cultures, if not overripe at the start, have good keeping quality at temperatures ranging from 32° F. to 75° F., but whey off readily at about 100° F.

3. Twenty-five per cent of B. bulgaricus culture added to the Bact. lactis acidi culture improves the flavor of the latter, gives it more body and checks any tendency to wheying off, particularly so at 100° F., or lower. If exposed at 100° F. for too long a period, the product becomes too acid and unpalatable, due to the renewed stimulated growth of B. bulgaricus in the mixture.

4. Mixed cultures of B. bulgaricus and Bact. lactis acidi in pasteurized whole milk have a superior flavor and a somewhat better keeping quality than those in skim-milk. This, no doubt, is due to the presence of milk fat.

5. Twenty-five per cent of B. bulgaricus culture, added to the buttermilk obtained from pasteurized ripened cream, effectively checks its tendency to whey off, gives it a better body and improves the flavor, which otherwise becomes old and flat.

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THE CONTROL OF PUBLIC MILK SUPPLIES BY THE USE OF THE MICROSCOPIC METHOD[1]

ROBERT S. BREED AND JAMES D. BREW

From New York Agricultural Experiment Station

At the Montreal meeting of the Society of American Bacteriologists in January, 1914, a report (1) upon the usefulness of the direct microscopic method of controlling public milk supplies was given and the conclusion was reached that this method gave promise of great usefulness. Soon afterward, plans were made for testing out the matter in a practical way. Today we are ready to give a preliminary report upon our findings.

The work which has been done consists in part of the examination of 1930 samples of market milk at the Hobart, N. Y., laboratory conducted by the Lederle Laboratories for the Sheffield Farms-Slausson, Decker Company. At this place thousands of agar plate-counts are being made yearly from samples of the milk delivered by farmers to three of the grade A plants operated by this company. Through the courtesy of Dr. H. D. Pease of the Lederle Laboratories we were permitted to use the results secured by the use of the agar plate method for a comparison with the results secured by using the microscopic method.

This work having demonstrated to our satisfaction that it was possible to grade milk by microscopic examination in at least as fair a manner as that accomplished by the use of the agar plate method, we persuaded the two local milk companies (White Springs Farm Dairy Company, and Geneva Milk Company of Geneva, N. Y.), to allow us to grade the milk which they were receiving by the microscopic method during a period of two years and to pay the farmers on the basis of our grading. The work of grading this milk was begun in a preliminary way on February 1, 1915, but the contracts did not go into effect until April 1, and the total period of our experiment will not be completed

[1] Read before the Laboratory Section of the American Public Health Association, Cincinnati, October 24, 1916.

until April 1, 1917. Thanks to the interest of the men in charge of the milk companies, their coöperation has been genuine and very helpful.

In the course of this work 9387 samples of milk have already been examined and graded by the microscopic method described in Technical Bulletin 49, (2) recently issued by the New York Agricultural Experiment Station. Counts have been made by both the microscopic method and the agar plate method in more than 600 cases. At the same time, through the courtesy and very effective coöperation of our local board of health, the effect of paying the farmers on the basis of the quality of the milk has been noted. Very little local publicity has been given to the work and the people of Geneva scarcely know that it has been done. The farmers, on the other hand, have heard of it frequently, as the results of all analyses have been mailed to them immediately after their completion, at least one visit has been made to every farm, and special studies and analyses have been made in those cases where the farmers continued to bring in poor quality milk. Very little use has been made of the dairy score card other than to carry out the requirement of the state board of health that the farms be scored at least once a year. As a result of the work which Dr. H. A. Harding did with the same group of men in 1907 to 1911 (3), nearly all of them were enabled to meet the minimum requirement of a score of 20 per cent for equipment and 35 per cent for methods though the general average score was lower than in 1911. In all cases where farmers continued to bring milk containing few bacteria, they have been left to run their own business even if they had a tumble-down stable with the manure heap piled against the barn and and many other conditions which were far from ideal.

DETAILED DISCUSSION OF THE RESULTS OBTAINED AT HOBART

The examinations of market milk which were made at Hobart were made during February, March and July of 1914. In view of the improvements in the handling of large numbers of samples for routine microscopic examination which were devised later,

the technique used at Hobart cannot be regarded as entirely satisfactory.

The plating technique used in the routine work would meet practically all of the requirements of the Standard Methods except that the plates were incubated for five days at 20° to 24°C. Only two plates were made from each sample, one being made from a dilution of 1: 100 and the other from a dilution of 1: 1000. The final count was ordinarily made from a single plate. The plating was done by a representative of the Lederle Laboratories.

The samples of milk were taken from individual 40-quart cans of milk as delivered by the farmers to the milk stations, located at Bloomville, South Kortright and Cobleskill. At these places, the farmers were paid a premium for delivering milk with a count less than 60,000 per cubic centimeter in the winter time and 100,000 per cubic centimeter in the summer time.

During February and March, 1504 samples of milk were examined by the microscopic method and graded "A" if it was thought that they would give a plate count under 60,000 per cubic centimeter; "B" if over 60,000. The ratings given were found to agree with those given as a result of the agar plate counts in 1339 instances (89.03 per cent). In 79 cases where the two gradings did not agree, it was because more than 60,000 colonies developed per cubic centimeter. In four of these cases the plate count was higher than 200,000 per cubic centimeter. In 86 instances where bacteria were found so abundantly by microscopic examination that it was concluded that the plate count would exceed 60,000 per cubic centimeter, later events revealed plate counts less than this, many of them being below 10,000 per cubic centimeter. In 10 of the 86 cases, bacteria were very abundant in the milk, 3 of the 10 showing a predominant long-chain streptococcus flora.

During July, 426 additional samples were examined and graded. Where it was thought that the milk would give plate counts below 100,000 it was graded "A," above 100,000 it was graded "B." The rating by both methods agreed in 362 cases (84.95 per cent). In 21 cases the microscopic rating given was "A," while the plate

count proved to be higher than 100,000. In 43 cases the microscopic rating given was "B," while the plate count proved to be less than 100,000.

Many of the discrepancies noted in these gradings occurred in the case of samples which might properly be regarded as border line samples; but there were occasional very wide discrepancies which could not be so regarded. It was impossible to decide, with the data at hand, whether the fault lay with the microscopic or with the plate method, or whether both were at fault. The percentage of agreement cannot be regarded as especially good, for it must be remembered that even if the matter were ruled entirely by the laws of chance the percentage of agreement would be 50 per cent.

DETAILED DISCUSSION OF RESULTS OBTAINED AT GENEVA

All of the work done at Geneva has been done under much more carefully controlled conditions. Microscopic counts have been made on all smears where the grade of the milk was doubtful and definite numbers have been selected as border lines between the grades, thus eliminating personal judgment so far as possible. In those cases where agar plate counts have been made, plating has been in triplicate and from three different dilutions (1: 100, 1: 1000, and 1: 10,000). Incubation of plates has been for five days at 21°C., followed by two days at 37°C.

In the case of 355 comparative plate and microscopic counts which have been summarized, 305 samples which showed fewer than 1,000,000 individual bacteria by the microscopic count developed fewer than 200,000 colonies per cubic centimeter, 19 samples which showed more than 1,000,000 and less than 10,000,000 individual bacteria developed between 200,000 and 1,500,000 colonies per cubic centimeter on agar, while 6 samples which showed more than 10,000,000 individual bacteria developed more than 1,500,000 colonies per cubic centimeter. If the limits which have been given are accepted as the limits between "good," "medium" and "poor" milk, then there would be an agreement in rating by the two methods in the case of 330 of the

355 samples (92.95 per cent). The discrepancies noted were as follows: 11 samples of milk showed less than 1,000,000 individual bacteria and plate counts over 200,000 and less than 1,500,000 per cubic centimeter. One sample showing a microscopic count as above showed a plate count over 1,500,000; 8 samples of milk, showing more than 1,000,000 and less than 10,000,000 individual bacteria gave plate counts less than 200,000; 5 samples with microscopic counts as just given showed plate counts of more than 1,500,000 per cubic centimeter. All samples showing more than 10,000,000 individual bacteria per cubic centimeter gave plate counts in excess of 1,500,000. In other words, four out of a possible six types of discrepancies were found to occur.

In view of the fact that three grades were recognized in this work in place of the two at Hobart, it should be noted that the improvement in agreement in grading is very much greater than that indicated by the increase in percentages from 89.03 and 84.95 to 92.95 respectively. The result of the work done at Geneva has convinced us that it is impossible to secure very much better agreement in grading by the two methods than 90 to 95 per cent. The variableness in the size and compactness of the groups of bacteria found is alone sufficient to cause the ratio between plate counts and individual counts to be so variable that 100 per cent of agreement is unattainable. In addition to this, there is clear indication of the presence of a relatively small number of samples which contain either living bacteria incapable of growth on agar or bacteria which are dead.

In view of these conditions, the control work which has been done at Geneva since February 1, 1915, has been done in complete disregard of all agar plate counts, sole dependence having been placed upon the microscopic method of examination. Samples have been collected from individual 40 quart cans of milk as they were delivered at the milk stations between 6.30 and 8.30 a.m. Between 45 and 70 samples have ordinarily been collected at one time, the exact number depending upon the number of cans delivered. They have been collected at least once weekly and during two seven day periods every can of milk delivered at one of the stations was sampled. The work of collecting and ex-

amining the samples has usually been done by one of the authors (Bw.) (during his absence on vacation the work was done by Mr. W. D. Dotterrer). The report on the samples has ordinarily been ready to mail to the farmers at 3.30 p.m. Where there was anything of especial interest, the results have been telephoned. Age and temperature records have been kept as well.

No attempt has been made to make exact counts, except in the case of samples whose grades were doubtful. The reason for this was that the greatly increased amount of labor involved gave very little return in the way of valuable records. Milk having less than 1,000,000 individual bacteria per cubic centimeter has been classed as "good," this being practically equivalent to milk having a plate count of less than 200,000 per cubic centimeter. No attempt has been made to distinguish between "good" and "excellent" milk, though, as shown by the work done at Hobart, this might have been done. Milk having more than 10,000,000 bacteria per cubic centimeter was rated as "poor," this standard being apparently but little more lenient than the 1,500,000 plate count per cubic centimeter used to distinguish between B and C milk in the New York State Sanitary Code.

The greatest number of samples handled by one man in any one day was 105. On October 17, 1916, one man prepared his collecting tubes, went to a milk station one mile distant, collected 76 samples of milk, returned to the laboratory and prepared and examined these samples of milk grading them "excellent," "good," "medium" and "poor," entered the results and mailed the reports back to the farmers within seven hours time. The actual time used in making the microscopic preparations was one hour and fifteen minutes. The examination of the smears, including the preparation of the reports for the farmers took two hours. If larger numbers of samples were handled and the work organized so that the work of collecting and of examining samples were done by separate persons, the work could be done equally well in a shorter time than this. The complete record of the 76 samples referred to has been given in table 1 in order that all may have an opportunity to see their value. The original records also showed which of the "excellent,"

"good," etc., cans were p.m. and which were a.m. milk, thus giving a record of the approximate age of each can of milk. If the work had been done by the routine plating method, the records would have shown definite counts but would have failed to show the type of organism present. Moreover the labor, expense of equipment and time involved in securing them would have been much greater.

A summary has been prepared (table 2) which shows the results obtained during the first twelve months. No unexpected difficulties were met with in carrying out this system of grading and very few complaints of unfair treatment from the farmers have been received. These have been very easy to handle, as all microscopic preparations have been kept on file. Whenever a farmer came to the laboratory to object, he was shown the milk from his own herd under the microscope with the bacteria in it. An especial effort has been made to get the farmers to come to the laboratory and they have been found to be much more interested in looking through a microscope at the bacteria themselves than in looking at colonies on agar plates. In many cases, men have brought samples of milk to the laboratory and preparations have been made from them at once, and shown to them. All of the operations being simple and easily understood, it has been possible to convince even the most ignorant and skeptical farmers that bacteria were real things and that they did not occur in large numbers in milk which was properly cared for.

A copy of the form letter used in reporting the monthly grade has been included in this paper as it gives the rules used in computing these grades.

Mr.....

Dear Sir:

The following is a report of the analyses made on the milk delivered by you during the month of.....

Total number of cans analyzed.....

Number of cans rating as { Good..... Medium..... Poor.....

Your monthly rating is.....

Yours truly,

.....

Asst. Bacteriologist.

TABLE 1

Laboratory record prepared from 76 samples of market milk taken by one person from individual 40-quart cans at a single milk station on October 17, 1916

FARM NUMBER	TEMPERATURE MILK		NUMBER OF CANS	NUMBER OF COWS	NUMBER OF CANS RATED AS				NOTES ON SAMPLES	NOTES ON DAIRY
	p.m.	a.m.			Excellent	Good	Medium	Poor		
	°F	°F								
1	54	71	8	40	2	4	2		Cocci, Bact. lactis acidi and rods in medium cans	Excellent stable and equipment
2	57	78	3	18			2	1	Bact. lactis acidi and rods	Good stable and equipment. Men dirty
3	52	68	4	15	4					Fair dairy. Everything kept clean
4	50	72	4	18		4				Good stable and equipment. Fairly clean
5	52	72	4	20		2	2		Large rods and cocci	Fair stable and equipment. Machine milked
6	50	71	4	20		4				Good stable and equipment. Machine milked
7	51	62	3	10	3					Fair dairy. Everything kept clean
8	51	66	2	8	1	1				Fair dairy. Not quite so clean
9	50	58	2	8	1	1				Dilapidated stable and equipment. Fairly clean
10	52	58	4	15		4				Stable poor. Everything dirty
11	48	54	2	8	2					Fair stable and equipment. Very clean
12	46	58	2	7	2					Dilapidated stable and equipment. Dirty
13	52	62	10	50	5	5			Few streptococci in "good" cans	Good stable and equipment. Not clean. Garget
14	51	62	6	48			6		Bact. lactis acidi and cocci	Good stable and equipment. Dirty milking machine
15	52	56	12	60	10	2				Excellent stable and equipment. Clean
16		56	1	12		1				Poor stable and equipment Clean
17	50	66	2	8	2					Fair stable and equipment. Fairly clean
18		61	1	6		1				Good stable and equipment. Clean
19	48	66	2	6	2					Fair stable and equipment. Clean
	Total...76				34	29	12	1		

TABLE 2

Summary, showing the grading of milk delivered between February 1, 1915 and February 1, 1916 to two local milk companies

DAIRYMAN NUMBER	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	TOTAL CANS GRADED	NO. GRADED GOOD	NO. GRADED MEDIUM	NO. GRADED POOR	PER CENT OF TOTAL GRADED GOOD
1	G	G	G	G	G	G	G	G	G	G	G	G	107	106	1		99.06
2	G	G	G	G	G	G	G	G	G	G	G	G	124	122	2		98.38
3	G	G	G	G	G	G	G	G	G	G	G	G	117	115	2		98.29
4	G	G	G	G	G	G	G	G	G	G	G	G	142	141		1	97.91
5	G	G	G	G	G	G	G	G	G	G	G	G	118	115	3		97.45
6	G	G	G	G	G	G	G	G	G	G	G	G	106	103	3		97.17
7	G	G					G	G	G	G	G	G	59	57	2		96.61
8	G	G	G	G	G	G	G	G	G	G	G	G	152	146	6		96.05
9	G	G	G	G	G	G	G	G	G	G	G	G	216	207	9		95.83
10	G	G	G	G	G	G	G	G	G	G	G	G	122	116	6		95.08
11	G	G	G	G	G	G	G	G	G	G	G	G	118	112	6		94.91
12	G	G	G	G	G	G	G	G					67	63	4		94.03
13	G	G	G	G	G	G	G	G	G	G	G	G	183	169	14		92.35
14	G	G	G	G	G	G	G	G	G	G	G	G	116	107	9		92.24
15	G	G	G	G	G	G	G	G	G	G	G	G	163	150	13		92.02
16	G	G	M	G	G	G	G	G	G	G	G	G	125	116	8	1	91.33
17	G	G	G	G	G	G	M	M	G	G	G	G	331	300	30	1	90.09
18	G	G	G	G	G	G	G	G	G	G	G	M	107	96	11		89.72
19	G	G	G	G	G	G	G	G	M	G	G	G	205	177	27	1	85.50
20	G	M	G	G	G	G	M	G	G	G	G	G	155	134	20	1	85.35
21	G	G	M	G	G	G	G	G	G	G	G	M	315	275	35	5	84.61
22	G	G	G	G	G	G	M	M	G	G	G	G	146	129	13	4	83.63
23	G	G	G	G	M	G	G	M	G	G	G	G	118	100	17	1	83.33
24	G	G	G	G	M	M	G	G	G	G	G	G	115	97	17	1	82.90
25	G	G	G	G	G	G	G	M	G	G	M	G	396	331	63	2	82.75
26	G	G	G	G	G	M	G	M	G	G	G	G	106	92	11	3	82.14
27	G	G	G	G	G	G	M	G	G	G	G	G	120	100	19	1	81.96
28	G	G	M	G	G	M	M						64	52	12		81.25
29					G	M	G	M	G	G	G	G	66	54	11	1	79.41
30	G	G	M	G	M	M	M	M	G	G	G	G	125	102	17	6	74.45
31	G	G	M	G	G	M	M	M	G	G	M	M	185	135	49	1	72.19
32	G	G	M	G	G	G	M	M	M	M	G	G	382	250	131	1	65.10
33	M	M	G	G	G	G	M	M	M	G	G	G	148	107	31	10	63.69
34	M	M	G	G	G	M	M	M	G	M	M	M	214	148	50	16	60.16
35	G	G	M	M	M	M	M	M	G	M	G	M	207	115	79	13	49.35
36	M							G	M	M	M		68	33	26	9	37.07
Totals													5608	4772	757	79	82.76

Good.—Less then 1,000,000 individual bacteria per cubic centimeter. Practically equivalent to a plate count of less than 200,000 per cubic centimeter. Satisfactory for pasteurization for grade A.

Medium.—More than 1,000,000 and less than 10,000,000 individual bacteria per cubic centimeter. Satisfactory for pasteurization for grade B.

Poor.—More than 10,000,000 individual bacteria per cubic centimeter.

Rules for Computing Monthly Ratings

1. Where a man brings not more than 25 per cent of his milk of "medium" grade he may still be given a "good" rating.
2. Where a man brings not more than 25 per cent of his milk of "poor" grade he may still be given a "medium" rating.
3. In computing percentages, one can of medium milk shall be counted as offsetting 3 cans of "good" milk; likewise, 1 can of "poor" milk as offsetting 3 cans of "medium" milk.

There are a great many interesting and suggestive things which appear in the summary (table 2). Only the most important of them can be referred to here. One of the things which has been noted ever since microscopic methods have been used for routine milk control has been the ease with which it was possible to recognize milks containing long-chain streptococci. Early in this work a record of all samples containing large numbers of these organisms was started. It was found almost at once that such organisms would be frequently found in large numbers in a single can of p.m. milk and in a single can of a.m. milk from the same farm. Usually these organisms were found in among masses of cells. These characteristics, coupled with the well known prevalence of udder infections, led us to suspect the cause at once. Consultation with the farmer failing at times to locate the offending animal, it has frequentlly been necessary to go to the farms and take samples from each individual cow. These samples were either examined microscopically as soon as the laboratory was reached, or more frequently, they were allowed to stand over night at room temperature before examination. After the cow was located, it was sometimes necessary to return to the farm and take samples from the individual quarters in order to find the exact seat of the trouble. While it has usually been possible to recognize at least some slight indication of inflammation or garget after the cow was found, yet in many cases it was so slight that the farmer cannot be blamed for having saved the milk. In one instance where a case of this sort occurred, the number of bacteria discharged from one quarter of the udder of a single cow contained enough streptococci to give a "medium" rating to a 40-quart can of milk.

Four of the 40 herds from which milk has been sent to these two

milk companies during the past twenty months were found to show troubles of this sort more or less continuously. So far as the records show there are only 8 of the 30 men who have delivered milk throughout this period who have done so without bringing a single can of streptococcus-milk. Out of a total of 9387 cans of milk which have been examined, 309 (3.29 per cent) have shown a predominant long-chain streptococcus flora of more than 1,000,000 individuals per cubic centimeter. Or to put it in another way, 21.4 per cent of all the high count milk received was streptococcus-milk; or one-fifth of all the trouble due to high count milks was caused by udder troubles. Conditions similar to these have been indicated by the work of several previous investigators, (4) but these records are apparently the first which have ever been kept in a way which measures the relative amount of trouble caused in this way. There is no apparent reason why troubles of this sort should be more frequent about Geneva than elsewhere, nor is the amount of clinically evident garget in the herds any more prevalent than elsewhere so far as our experience goes.

Some may question our conclusion that udder infections were the source of the trouble in all cases where streptococci formed an abundant and predominant flora. It is true that the evidence of this fact is all circumstantial but it seems conclusive nevertheless. The most conclusive evidence is furnished by the fact that it has been very easy to find the individual cow in all of the cases, where the matter has been investigated. Streptococci were frequently seen in milks in small numbers where they did not form the predominant flora and where they were not associated with cells. In these instances it is possible that they may have come from feces or other sources.

It is scarcely necessary to point out the importance of these findings to those who are interested in the sanitary control of the public milk supply. It should be noted that Moak (5) has reached somewhat similar conclusions from the results obtained in the routine control of the certified milk of Brooklyn, N. Y. He says, "In working entirely upon a bacterial standard as we do in the production of certified milk, we have come to know

that mastitis is a cause of high counts." "The mastitis causing high bacterial counts in our studies has almost without exception been due to streptococci."

In this investigation only a few samples have been found where our attention has been called to bacteria, other than these streptococci, which were apparently derived from the udder. In some cases, a small micrococcus (possibly a short-chain streptococcus of the "brevis" type) has been seen which was associated with cells and had a distribution in cans of milk similar to that noted in the case of the long-chain streptococci. In one case this was traced back to the individual cow but unfortunately the matter could not be followed up at the time. No samples have been noted which contained bacteria which had the appearance of either the tubercle or of the abortion bacillus though it is quite possible that such samples have been present. Further investigations along this line would reveal many other facts of importance in the control of milk supplies. If more were known concerning the source of the various types of bacteria seen, much help could be given to the farmers in their efforts to produce low count milk. In other respects, the results obtained from the microscopic examination of milk were of equal value to those obtained from agar plate counts and they were used in the same way.

In conclusion it should again be emphasized that no unforeseen or unsurmountable difficulties have been met with in establishing a control of the public milk supply of Geneva by the microscopic method of examination. This system of control appears to have practically all of the advantages of similar systems of control carried out with the agar plate method together with some very important additional ones. In particular these are the chance to control easily and effectively all milk brought in from cows with infected udders, and a possibility of finding many sources of trouble without the necessity of making inspection visits to the farm; this being done by a method which greatly exceeds the agar plate method in simplicity. In view of the comparative work done, there can no longer be any question but that the results are at least as accurate as those secured by

the agar plate-method and there is little question but that a much fairer estimate of real conditions is secured than is ever the case where agar plate counts are carried out by the routine methods ordinarily in use.

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SOME BACTERIOLOGICAL TESTS OF THE MILK CLARIFIER

JAMES M. SHERMAN

Agricultural Experiment Station, State College, Pennsylvania

INTRODUCTION

The present interest in the clarifier as a factor in milk hygiene is shown by the discussions which its use has recently provoked (1). This machine has been taking an increasingly prominent place in the dairy industry during the past few years. It has been used especially in city milk depots, ice cream plants and renovated butter factories where it performs the function of removing visible dirt. At present the milk clarifier is being used to some extent by certified milk producers, many of whom believe that besides the removal of gross impurities the clarification of milk improves its keeping quality, diminishes its bacterial count, and even makes it a more healthful food product. From the point of view of the dealer who is handling milk of ordinary quality it must be acknowledged that the removal of visible dirt is an advantage, but as to whether the producer of high grade milk is justified in going to the expense of installing and maintaining a milk clarifier there may be reason for doubt. It was principally with the view of establishing the merits of the machine from the standpoint of the high-grade milk producer that this investigation was undertaken.

DETAILS OF EXPERIMENT

The milk used in this work was of a grade equal to that of certified milk though not licensed by a medical milk commission. Two milk clarifiers of standard type, both of which are widely used, were tested in this study. They are designated for convenience as "A" and "B." These machines were well cleaned and the working parts thoroughly steamed after use so that the contamination from this source was probably as low as is ob-

tainable under commercial conditions. Tests were made on the effect of the clarifying process on the number of bacteria, the subsequent activity of the organisms, and the keeping quality of the milk.

BACTERIAL COUNT

Samples of milk were taken before and after clarifying and were examined for their bacterial contents. The counts were made by the plate culture method using lactose agar and incubating the plates at 37°C. for forty-eight hours. On twenty-four tests the milk before clarification contained from 1,860 to 11,400 with an average of 4,720 bacteria per cubic centimeter, while the milk after the process contained from 3160 to 13,800 with an average of 7120 bacteria per cubic centimeter. The data obtained are given in table 1.

The increase in the number of bacteria in the clarified milk is of course only an apparent one and is due to the agitation caused by the machine which breaks up the clumps of bacteria, thus increasing the count as determined by the plate culture method. However, this may be considered a disadvantage since, by the methods used in municipal laboratories for the bacterial analysis of milk, clarification increases the apparent number of bacteria and hence to a certain extent lowers the apparent quality of the milk.

ACTIVITY OF ORGANISMS

It might very reasonably be argued that the clarification of milk really improves its bacteriological condition since the increase in the number of organisms is only an apparent one and many bacteria are thrown out with the sediment. On the other hand, it might be contended that the breaking apart of the clumps of bacteria would lead to a more rapid subsequent growth of the organisms remaining. It would be very desirable, therefore, to obtain information concerning the relative physiological activities of the microorganisms in ordinary and clarified milks but such information is difficult to secure with any means we now have at our disposal. The reduction of methylene blue is

probably the most accurate method which may be utilized for measuring the actual vital activities of the bacteria in milk, since practically all of the organisms which develop in milk have at least a slight reducing power for this compound. Reduction tests were made upon the milks in order to throw some light

TABLE 1

Effect of clarification on the bacterial count of milk

TEST NUMBER	MACHINE	BACTERIA PER CUBIC CENTIMETER	
		Before clarification	After clarification
1	A	3,700	6,100
2	A	3,800	6,300
3	A	5,500	8,500
4	A	2,900	6,300
5	A	4,200	6,200
6	A	4,100	6,200
7	A	3,400	7,400
8	A	3,900	6,100
9	A	3,400	4,900
10	A	3,000	4,900
11	A	3,200	6,800
12	A	4,300	9,600
13	B	3,300	5,600
14	B	5,900	7,300
15	B	9,300	13,800
16	B	4,800	7,600
17	B	1,800	3,100
18	B	2,500	3,300
19	B	2,900	3,700
20	B	11,400	13,400
21	B	4,300	6,400
22	B	3,600	4,500
23	B	10,300	13,400
24	B	7,800	9,300
Average.....	A and B	4,720	7,120

on this point. The tests were made by mixing 10 cc. of milk with 1 cc. of a solution of methylene blue (0.05 per cent medicinal methylene blue in physiological salt solution) and incubating at 37°C. until the color disappeared. In making these tests five check samples were run on each milk. Eight such tests were run and in every case the reduction took place sooner in

the clarified milk. The differences were well marked and indicate that the clarifying process actually stimulates the activity of the organisms contained in the milk. In table 2 are presented the results obtained from these tests.

TABLE 2

Reduction of methylene blue by clarified and unclarified milk

TEST NUMBER	MACHINE	TIME OF REDUCTION IN HOURS	
		Before clarification	After clarification
1	A	21.3	18.1
2	A	14.3	13.6
3	A	19.8	13.9
4	A	17.9	13.6
5	B	13.3	12.5
6	B	18.5	17.3
7	B	20.8	19.1
8	B	17.1	15.6
Average.....	A and B	17.9	15.5

Tests were also made of the rate of acid formation in the milks by placing samples at 37°C. for fifteen hours and then determining the amount of acid produced. Similar trials were made in which the milks were incubated at 10°C. for ten days. The results are given in tables 3 and 4.

TABLE 3

Development of acid in milks held at 37°C. for fifteen hours

TEST NUMBER	MACHINE	PER CENT LACTIC ACID	
		Not clarified	Clarified
1	B	0.264	0.310
2	B	0.268	0.346
3	B	0.337	0.380
4	B	0.257	0.290
5	B	0.283	0.360
6	B	0.228	0.241
7	B	0.234	0.247
8	B	0.257	0.297
Average.....	B	0.266	0.309

TABLE 4

Development of acid in milks held at 10°C. for ten days

TEST NUMBER	MACHINE	PER CENT LACTIC ACID	
		Not clarified	Clarified
1	A	0.571	0.679
2	A	0.574	0.623
3	A	0.551	0.560
4	A	0.562	0.599
Average.....	A	0.565	0.615

As may be seen from table 3 the development of acid at 37°C. was greater in the case of clarified milk in all of the comparisons that have been made. Even at 10°C., at which temperature bacterial growth is greatly retarded, the development of acid was greater in the limited number of tests made. Although it would not be safe to draw the conclusion that clarified milk is of poorer keeping quality than unclarified milk under commercial conditions, it may be quite definitely stated that the clarifier does not enhance the keeping quality.

STREPTOCOCCI

There is a belief among many dairymen that clarification removes certain harmful agents from milk and thus makes it a safer and more wholesome food. This rather hazy impression has doubtless been conveyed through the advertisement of the fact that the clarifier throws out some of the products of inflammation, such as leucocytes or pus cells, which find their way into milk in large numbers whenever any of the milk-producing animals suffer from udder troubles. The impression has been gathered by some that the causal organisms of mammitis are likewise removed by the clarification of milk. That some of the streptococci are removed would appear obvious, but that enough of these organisms are taken out of milk by the clarifier to have any sanitary significance may be doubted. The fresh milk used in this work was found always to contain udder streptococci which are morphologically identical with the streptococcus of

mammitis. Tests were made therefore of the clarified milk for the presence of these organisms. Of fifteen samples taken on as many different days streptococci were found in every case in apparently just as great numbers as in the fresh milk.

DISCUSSION

The work here reported agrees with the more extensive study of Hammer (2) with reference to the bacterial count of milk.

The data presented concerning the activity of the bacteria in clarified and unclarified milk are believed to be of special significance since they show that the breaking apart of bacterial clumps leads to a more rapid subsequent growth. Also it would seem that the ordinary laboratory method of counting bacteria in milk is vindicated. If such methods as cause an increase in the apparent number of bacteria stimulate their activity proportionately the colony count has lost none of its integrity.

The failure of the clarifier to remove streptococci is interesting in view of the rather extravagant claims that have been made for this machine as an eliminator of harmful organisms. That there exists a great difference in the specific gravity of pathogenic and non-pathogenic bacteria has certainly not been established. Even though the harmful types were of greater density many could not be thrown out of milk because of contact with the relatively much larger fat globules. It is well known that a large portion of the tubercle bacilli are thus carried with the cream in the separation of milk. The work of Hammer further shows that less than one-half of the body cells of milk are removed by the clarifying process. The conclusion seems obvious that the clarifier is not of hygienic significance.

If the clarification of milk can not be recommended on sanitary grounds it is pertinent to question whether it is justifiable from the purely economic standpoint. For the certified milk producer it would seem that the process has little to recommend it since visible dirt, other than that removed by the ordinary practice of straining, should not be present to a noticeable extent. The foregoing tests indicate that the process is in fact detri-

mental rather than beneficial when applied to milk of a high grade. It is only to such milks that the conclusions here drawn are meant to apply. For milks of poorer quality the removal of sediment is of obvious advantage; but may it not be possible to remove the visible impurities by a much cheaper process than clarification?

SUMMARY

From the foregoing data it is seen that the number of bacteria in high grade milk as determined by the plate culture method is considerably increased by the milk clarifier. The clarification of milk does not improve its keeping quality; on the other hand it appears that the activity of the bacteria may even be stimulated by the process, as indicated by the methylene blue reduction test and the development of acidity. The clarifying process does not appear to have any hygienic significance as evidenced by its failure to remove streptococci to a measurable extent.

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A SIMPLE SALT TEST

F. W. BOUSKA

American Association of Creamery Butter Manufacturers, Chicago, Illinois

A determination of salt in butter has great commercial value. It shows the uniformity of salting as well as the percentage of salt in each churning. The only way to verify whether the churn over run is as high as it should be commercially and not higher than it ought to be legally is to compare it with the chemical over run. To calculate the chemical over run a knowledge of the percentage of water and salt is necessary. In butter made the usual way it is close enough to assume that the curd is 1 per cent. Again, the question whether a Babcock test of cream should be read according to one authority or another authority is a personal question. To prove the testing of cream by ascertaining whether the butter contains the fat shown by the test is to verify the test by mathematical facts and not by personal opinion. To ascertain the amount of fat in butter by means of creamery facilities, a moisture and salt test are necessary.

After thus emphasizing the value of a salt test I hope to encourage its use by buttermakers by giving a simple method. In it I strive to the utmost to avoid unusual equipment and to use the facilities at hand. It calls for only one piece of apparatus which is not found in every creamery. This is a burette. By using a 5 cc. burette the readings are made directly and are quite accurate. The solutions are used in such small quantities and are so weak that the consumption of chemicals is far less than any other test known to me. This is particularly timely in this period of conservation.

Standard salt solution. Balance a piece of paper on the left pan of the moisture scale. The lower moisture rider can be used to assist in the balancing. Move the rider on the upper beam from the 0 mark to the 10 per cent mark. Add butter salt till the scale balances. The more carefully this is done the more accurate the salt test will be. This, now, is 1 gram of

salt and is 10 per cent of 10 grams of butter, the quantity usually used for the moisture test. Cautiously sweep the salt into a half-pint milk bottle. Fill about half full of distilled water to allow mixing to dissolve. Be careful to dissolve completely. When dissolved add water brimming full at room temperature, and mix by carefully pouring into another bottle. It is not necessary that these bottles hold exactly ½ pint. But it is essential that all the half-pint milk bottles used in this method hold the same quantity. Bottle this solution for future use in checking silver solution. It will keep as long as it lasts.

Silver solution. Again balance a piece of paper on the left pan. This time the upper moisture rider can be used to assist in balancing. Shift the lower rider from 0 to the 20 per cent mark. Put the 10 gram weight on the right pan. Place silver nitrate on the left pan to approximately balance. This is about 12 grams but does not have to be exact. Dissolve the silver in 1 quart of distilled water. Give it plenty of time to dissolve and mix well. Keep in a bottle of amber, blue, or green glass, or stoneware to protect against light. A bottle covered with paper serves well.

Indicator. Dissolve enough potassium or sodium chromate in distilled water to give a yellow color. This is usually a 10 per cent solution, but need not be definite. Sodium chromate ought to be cheaper and potassium bichromate will not do.

Provide a 5 cc. burette with a narrow tube so the $\frac{1}{10}$ marks would be far apart and easily read. The nozzle on the burette should have a fine opening and an easy working pinch cock so drops could be let out easily and under control. A brass or copper nozzle is good. If the wire pinchcock is stiff file the ring thin so it will work easily. Any burette will do but a 5 cc. is more accurate than a larger one.

Standardization. Place the silver in the burette. See that air is expelled out of the nozzle and that the bottom of the meniscus is at 0. By means of a pipette place 9 cc. of the standard salt solution into a white cup or other convenient container. Add enough chromate to give a yellow color. Carefully run in silver out of the burette to the 5 cc. mark. Fill the burette again and

carefully run in silver till a faint brick red color appears and remains permanent. Of course the silver and salt will be well stirred.

If it took 10 cc. of silver to neutralize the salt the silver solution has the correct strength. If 9 cc. of silver neutralized the salt the silver is 10 per cent too strong. Add 10 per cent water (1.6 ounces) by means of a butter color graduate. If 8.3 cc. produced the red color the silver is 17 per cent too strong. Add 17 per cent (2.7 ounces) of water.

The intention of the above directions is to make up an excessively strong preliminary solution of silver. It is easy and accurate to adjust it by adding water. But if the silver solution were weak it would be more difficult to calculate and weigh out the additional quantity of silver. This is further made difficult because the silver is of irregular strength and sometimes weakens with time. Butter salt has a definite strength, does not weaken with age, and is easy to weigh out. The strength of distilled water is 0. Thus it is easy to reduce the strength of a 110 per cent solution to 100 per cent. The 10 cc. representing 10 per cent salt or correct strength enables mental calculation for correction.

If it required 11 cc. of silver to give a brick red color in 9 cc. of standard salt, then the silver is 10 per cent too weak. Add 10 per cent more silver. Since the silver has only a 90 per cent strength 1.3 grams will be required.

In determining salt the chemist does not titrate to a brick red color. But since it is the custom among buttermakers to titrate to a brick red, I recommend it here. The test is correct if the silver is made to show 10 per cent at the brick red point.

After adjusting the silver with water or with more silver verify its correctness by titrating with the standard 10 per cent salt. If 10 cc. of silver is consumed the silver solution is correct.

Determination. Prepare the butter by puddling or working with a spatula, small paddle, paring knife, or teaspoon handle until not even the smallest drops of water are visible. This is a homogeneous mixture any portion of which will analyze the same.

Weigh 10 grams of this butter into a moisture cup or a tea-

spoon, or upon a small piece of parchment paper. Transfer into a half-pint milk bottle by means of hot distilled water poured out of a teapot. If the butter is on a piece of parchment paper it can be placed directly into the half-pint bottle. Melt the butter by shaking in half a bottle of hot water. This dissolves the salt out of the butter. Unless about four minutes is allowed to dissolve the salt the tests of the same sample may vary.

Fill the half-pint bottle brimming full with distilled water. This water for filling need not be hot. Mix by pouring into another bottle. Draw out 9 cc. by means of a pipette before the fat has risen to the top. If the fat has risen to the top the water below will still show practically the same percentage of salt. Titrate with the silver solution to a brick red color. Each cubic centimeter on the burette is 1 per cent of salt and each 0.1 cc. is 0.1 per cent salt.

What remains in the moisture cup after an Irish test has been made on a 10 gram sample may be used for a salt test. This saves again weighing out 10 grams of butter. The residue is transferred into a half pint bottle by repeated washings with hot water. In this case the salt is crusted by the heat and covered with curd and fat. Plenty of time should be given to dissolve it. In a creamery making a few churnings daily this method may be followed: Have as many numbered moisture cups as there are churnings. When the moisture test is finished set the cup aside to be tested at convenience that day or the next day.

By doubling the quantity of silver per quart of water (24 grams) the 17.6 cc. pipette may be substituted throughout for the 9 cc. pipette. Here again the main point is to adjust the silver solution so it would show 10 per cent salt when titrated against the standard salt. The 17.6 cc. pipette will of course consume twice as much silver as a 9 cc. pipette.

After the test is finished the silver in it has not disappeared and may be saved. Pour these test residues into a large bottle or stone jar. The silver will settle into a heavy paste. The clear solution is poured or syphoned off from time to time. In a year or two the accumulated cake of silver chloride is dried

and sold. I have known creameries to recover $80.00 worth of silver in a year.

My observation is that at least one-tenth of the silver solutions used in creameries are more than 10 per cent incorrect. Nearly all this irregularity arises from depending on the strength of silver nitrate of which a definite quantity is weighed out. Much better results can be expected by basing the test on the definite strength of butter salt.

A PLAN FOR CONTROLLING THE MILK SUPPLY OF THE SMALL TOWN

PERCY WERNER, JR.

From the Department of Dairy Husbandry, University of Missouri

The methods of milk control now in use are three: (I) The control of the sources of production and distribution; accomplished by inspection, usually with the aid of a score card. Under this plan which is widely used no attempt is made to judge the milk itself, the supervision being limited to the methods and equipment used in producing the milk. (II) Control by examining the milk as sold. This method, which is usually limited to use in the larger towns, since the expense of laboratory facilities makes it impractical for the small town, attempts to secure milk of certain specified chemical and bacteriological standards, leaving to the producer the task of marketing a product which will meet the requirements. (III) Safeguarding the consumer of milk by compulsory pasteurization. Seldom is this method the only means of control but it is very generally used for certain grades of milk at least. It of necessity cannot be used in small towns where milk is delivered by the farmers directly.

These three methods are combined in various ways by different cities. In Kansas City, Missouri, for instance, all three are used. Standards, both chemical and bacteriological are set, and regular laboratory analyses are made. The farms and distributing plants are inspected and minimum scores are required. The lowest grade of milk is required to be pasteurized.

The cost of carrying on inspection and laboratory analysis as at present done and the lack of central distributing plants where pasteurization could be done, puts these methods of control out of the reach of the average small town. Before efficient control can be exercised over the milk supply of small towns some method must be devised which will be efficient and at the same time within the reach financially of the small town.

As a result of some experimental work recently carried out

at the Missouri Experiment Station a method of control of the small milk supply has suggested itself to the writer. While making a sanitary survey of the milk supply of St. Charles, Missouri, a series of direct microscopic counts of bacteria was made of milk samples preserved in formalin. These counts made from milk from two to five days old, checked so perfectly with the counts from fresh milk that additional experiments were planned to determine the possibility of making the counts from preserved samples at the Station Laboratory instead of in the field.

The accuracy of the direct microscopic enumeration of bacteria in milk has been sufficiently proved by Breed and the New York Milk Commission (1), as shown by the following quotation from their report by H. W. Conn. "The direct microscopical examination of milk smears by the Breed Method will classify raw milk into grades A, B, and C, with about the same accuracy and much more quickly than the plate method of bacteriological analysis will do." It reveals the number of individual bacteria, both dead and alive and the groups. It will give a count of the leucocytes of milk and will show the presence of streptococci. If dead bacteria will be revealed by this method, then it seems plausible that a bacterial count could be made of milk preserved in formalin. If this should prove to be the case, this method of counting bacteria is subject to a very wide application.

It suggests for instance the possibility of securing a bacteriological control of the milk supply of the small city without the expense in the way of a laboratory and a bacteriologist or an expert inspector. The samples could be collected by a local agent, preserved with formalin and shipped to the Experiment Station or some laboratory where the bacterial count can be made. One central laboratory could thus make the tests of milk from all the small towns of the state. The expense of the testing could be divided among the individual towns. A person who is capable of taking the temperature and representative samples of milk from the dairymen could do all the work that would be required in the town. The sample bottles containing the preservative could be prepared at the laboratory and sent in sufficient numbers to the towns. If the bacterial count could

be thus determined, a satisfactory control of the milk would be possible. Tests for butter fat, water and solids not fat can all be made from a preserved sample. A test for preservative is perhaps the only test ordinarily applied to milk which could not be carried out with such a sample.

THE DIRECT MICROSCOPIC COUNT

The enumeration of bacteria in liquid cultures by means of the direct microscopic count has been used in a variety of ways ever since the time of Lister, Koch and Pasteur. It was first used to determine the approximate number of bacteria in suspension for use as a guide to the proper dilution necessary for plate counting. The first application of the method to milk analysis was made by Dr. F. H. Slack (2) who noticed a relationship between the plate count of bacteria in milk and the number of bacteria in stained centrifuged samples which he was examining for cell and streptococci content.

In 1914 Brew of the Geneva Experiment Station (3) published results of comparisons made at the Station upon the microscopic count of milk by the Breed and the ordinary plate methods, which indicate that milk can be as accurately graded by the one as by the other.

The value of formalin in the preservation of milk is well known. Whether or not it would interfere with the staining of bacteria in milk, had not been determined. That it did not, however, was proved by experiments by the author.

EXPERIMENTAL WORK

It was the purpose of the experiments described to determine whether the addition of formalin to milk would interfere with the successful grading of milk by preventing the staining of the bacteria after preservation for several days. If it should be shown that milk so preserved could be accurately graded according to the bacterial standards set by the New York Commission on Milk Standards, then the use of this method in the grading of milk for the small town as above described, would be

entirely practical. Microscopic counts were made of samples of whole milk of varying sanitary grades after which each sample was preserved in a closed container with formalin in the proportion of 1 part to 500. The containers used were one-fourth pint milk bottles fitted with rubber stoppers and tin clamps. The containers were the same as used in collecting samples in

TABLE 1

Microscopic count of bacteria in milk before and after preservation by formalin

SAMPLE	NUMBER OF BACTERIA BEFORE ADDING FORMALIN	NUMBER OF BACTERIA TWO DAYS AFTER	NUMBER OF BACTERIA FIVE DAYS AFTER
Old milk			
1	580,000	612,000	183,000
2	4,986,000	2,620,000	1,638,000
3	185,000,000	99,500,000	155,400,000
4	6,590,000	10,772,000	
5	2,268,000	1,320,000	
6	1,572,000	1,626,000	
7	2,466,000	2,004,000	
8	4,062,000	1,968,000	
Fresh milk			
9	48,000	12,000	
10	54,000	18,000	
11			
12	48,000	120,000	
13	18,000	6,000	
14	6,000		
15		12,000	

NOTE.—The above results are typical of over 50 samples counted.

the field. These containers have the advantage of being easily filled and cleaned. All air can be excluded and the stopper can be removed by admitting air on one side so that the sample can be agitated without danger of contamination. Counts were made from each of the preserved samples after two to five days with the results as shown in table 1.

DISCUSSION OF RESULTS

A brief discussion of the use of the bacterial count in the grading of milk will assist in making clear the significance of the con-

clusions drawn from the above data. Milk is usually graded into three grades which indicate the degree of cleanliness observed and the temperature regulation in the handling of the milk. Grade A, which according to the standards set by the Commission on Milk Standards by the New York Milk Committee (4), includes all milk containing under 100,000 bacteria per cubic centimeter, is milk of a high quality which has been produced under clean conditions and has been kept cold. Grade B which includes milk containing between 100,000 and 1,000,000 bacteria per cubic centimeter is milk which, though not to be condemned for raw consumption, has not been produced with the greatest degree of care. Grade C, containing over 1,000,000 bacteria per cubic centimeter, is milk so carelessly handled that it is generally considered to be unfit for consumption in the raw state.

The line of distinction between these different grades is very indefinite. The unavoidable error in the counting of bacteria by any method yet devised is such that it is impossible to say for instance, that milk containing only 90,000 bacteria per cubic centimeter is any better than milk containing 110,000. But the methods in use are sufficiently accurate to justify one in the conclusion that there is a marked difference in the sanitary quality of milk containing close to 1,000,000 bacteria per cubic centimeter and milk containing considerably under 100,000.

Examination of the data given above shows that in all but three cases the milk would be put in the same grade whether the count were made before or after preservation considering the grades to be as defined above: Grade A, under 100,000 bacteria per cubic centimeter; grade B under 1,000,000 and above 100,000; grade C, over 1,000,000. The fact that some samples varied as much as 30,000 does not at all interfere with the successful grading of the milk. In the case of the fresh milk where samples are reported as containing no bacteria, this simply means that the number is under 6000, as 6000 is the factor by which each bacterium on the microscopic field was multiplied, in arriving at the total number per cubic centimeter.

It is not believed that the number of samples tested is suffi-

cient to prove beyond doubt that formalin does not destroy the ability of some bacteria to accept analine dyes after two or five days preservation but it does at least clearly indicate that such is the case.

In the light of this evidence, it would seem to the writer that the laboratory control of the small milk supply could be easily and practically carried on by a central state laboratory where preserved samples could be sent for analysis.

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